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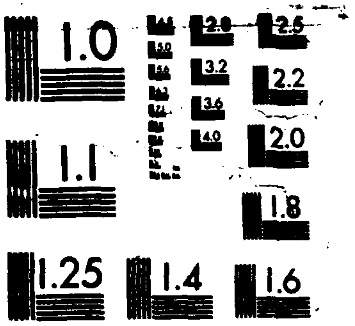

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AD-A204 542

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Design Memorandum No. 1

PHASE I GDM ON THE SANTA ANA RIVER MAINSTEM

including Santiago Creek

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

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Design Memorandum No. 1

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Including Santiago Creek
Volume 2, Prado Dam

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- Hydraulc Design
- Geology, Soils and Materials
- Cost Estimates
- Real Estate Requirements
- Site Restoration

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This volume accompanies the Main Report and Supplemental Environmental Impact Statement of the Phase II General Design Memorandum fo the Santa Ana River Mainstem including Santiago Creek, and contains the general design for the Prado Dam.

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Unclassified
SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

SYLLABUS

This volume accompanies the Main Report and Supplemental Environmental Impact Statement of the Phase II General Design Memorandum for the Santa Ana River Mainstem including Santiago Creek, and contains the general design for the Prado Dam.

A The recommended improvement to the existing flood control Prado Dam, which was completed by Corps of Engineers in 1941, consists of enlarging the reservoir capacity by raising the spillway crest 20 feet and the top of the dam 28.4 feet to elevations 563 and 594.4 feet, respectively. A new gated outlet structure capable of releasing 30,000 cubic feet per second, an auxiliary dike, and a dike along the Corona Expressway would be provided. Approximately 1,660 acres of land up to elevation 566 feet would be acquired for the enlarged reservoir. Interior dikes would be provided for the protection of the existing facilities at the Corona Sewage Treatment Plant, Alcoa Aluminum Plant, Corona Housing Tract, and California Institution for Women. The cost for the recommended improvement is estimated at $212,623,000, including $116,274,000 for land acquisition. (FR)

PHASE II GDM LISTING OF VOLUMES

Main Report and Supplemental Environmental Impact Statement:

Volume 1	Seven Oaks Dam
Volume 2	Prado Dam
Volume 3	Lower Santa Ana River (Prado Dam to Pacific Ocean)
Volume 4	Mill Creek Levee
Volume 5	Oak Street Drain
Volume 6	Santiago Creek
Volume 7	Hydrology
Volume 8	Environmental
Volume 9	Economics and Public Comment and Response

PERTINENT DATA FOR
ORIGINAL (1939) PRADO DAM AND SPILLWAY

Drainage area	sq mi	2,255
Dam (rolled earthfill)		
Crest elevation	ft msl (NGVD)	566
Maximum height above streambed	ft	106
Crest length	ft	2,280
Freeboard	ft	10
Spillway (detached, overflow concrete)		
Crest elevation	ft msl	543
Crest length	ft	1,000
Elevation of maximum water surface	ft msl	556
Outlet works (6 - gates)		
Conduit Dimension	ft	2-13.5x13.5
Length of conduit (including intake structure)	ft	786
Intake elevation	ft msl	460
Reservoir		
Area at spillway crest	acre	6,695
Capacity (gross) at spillway crest	acre-ft	217,000
Storage allocation below spillway crest		
Flood control	acre-ft	205,000
Sedimentation (50-year storage)	acre-ft	12,000
Reservoir-Design Flood		
Total volume (7 days)	acre-ft	275,200
Peak inflow	cfs	193,000
Peak outflow	cfs	9,350
Probable Maximum Flood		
Total volume	acre-ft	233,000
Peak inflow	cfs	289,000
Peak outflow	cfs	181,000

The primary purpose of the project is flood control. Recreational development has been included at the project by Act of Congress, but recreation was not considered a project purpose.

PERTINENT DATA FOR RECOMMENDED
PRADO DAM AND SPILLWAY

Drainage area	sq mi	2,255
Dam (rolled earthfill)		
Crest elevation	ft msl (NGVD)	594.4
Maximum height above streambed	ft	134
Crest length	ft	3,050
Freeboard	ft	4.5
Spillway (detached, overflow concrete)		
Crest elevation	ft msl	563
Crest length	ft	1,000
Elevation of maximum water surface	ft msl	589.9
Outlets works (6-gated)		
Size of conduit	ft	2x23Hx19W
Length of conduit	ft	800
Intake elevation	ft msl	470
Reservoir		
Area at spillway crest	acre	10,300
Capacity (gross) at spillway crest	acre-ft	362,000
Storage allocation below spillway crest		
Flood control	acre-ft	292,000
Sedimentation (1980 to 2080)	acre-ft	70,000
Reservoir-Design Flood*		
Total volume (4 days)	acre-ft	415,800
Peak inflow	cfs	254,000
Peak outflow	cfs	30,000
Probable Maximum Flood		
Total volume	acre-ft	1,543,000
Peak inflow	cfs	700,000
Peak outflow	cfs	578,000

*Reservoir Design Flood, equivalent to about a 190-year event, is 92% of the Standard Project Flood.

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Appendices

I. INTRODUCTION

Authorization

1-01 Authorization for construction of the project is contained in the Water Resources Development Act of 1986, (P.L. 99-662). The project for flood control is contained in the report of the Chief of Engineers for the Santa Ana River Mainstem, including Santiago Creek, California dated January 15, 1982, except that in lieu of the Mentone Dam feature of the project, the Secretary is authorized to plan, design and construct a flood control storage dam on the Upper Santa Ana River. The full authorization language is presented in the Main Report.

Scope and Purpose of Report

1-02 The purpose of this element of the authorized project is to provide additional capacity for storage of floodwaters and sediment by enlarging the existing Prado Dam Reservoir. The scope of post-authorization studies described in this volume of the memorandum includes establishment of the general and coordinated design of the proposed improvements. This Phase II GDM provides the basis for: (1) determination of the required project rights-of-way and easements, (2) update project design by incorporating latest environmental concerns, (3) update of the project costs, and (4) preparation of contract plans and specifications for modification of the dam embankment and construction of the dikes.

Local Cooperation

1-03 The division of Federal and non-Federal responsibilities for local cooperation are outlined in the Main Report.

II. PROJECT PLAN

Description of the Project Area

2-01 The Santa Ana River drainage area includes the southwestern slopes of the San Gabriel, San Bernardino, and San Jacinto Mountains; plus broad alluvial valleys in San Bernardino and Riverside Counties of southern California. Major tributaries to the Santa Ana River include Chino Creek, Lytle Creek, and Cucamonga Creek from the north, Mill Creek and San Timoteo Creek from the east, and Temescal Creek and Santiago Creek from the southeast portions of the drainage area (see pl. 1). At its mouth, the Santa Ana River has a total drainage area approximately of 2,450 square miles with elevations ranging from sea level at the Pacific Ocean to elevation 11,502 feet at Mt. San Gorgonio. The existing Prado Dam is located on the Santa Ana River just downstream from its confluence with Chino Creek, Cucamonga Creek, and Temescal Creek; the dam controls runoff from approximately 2,255 square miles including approximately 767 square miles of drainage area along San Jacinto River upstream from Lake Elsinore. Approximately 40 percent of the drainage area is mountainous and unsuitable for urban development. However, the remaining 60 percent of the land is considered to be a prime area for further development of the potentially giant industrial, commercial, and population center of the region--the Inland Empire.

2-02 Construction of the existing Prado Dam was completed in 1941, and approximately 3,500 acres of reservoir lands have been under Government jurisdiction, thus limiting major urban development. However, urbanization of the land adjacent to the reservoir area has been significant in recent years (pl. 2). Large housing and commercial development has occurred in the cities of Corona and Norco of Riverside County, and in the City of Chino in San Bernardino County. Highway 71 (Corona Expressway) has its southern terminus joining the Riverside Freeway (Highway 91) just south of Prado Dam. The Prado Dam reservoir area offers a large open space and the potential for recreation opportunities in the heavily urbanized southern California. Extensive recreation facilities have already been constructed on Federal Government land within the reservoir through a cooperative effort involving the Corps, the local counties and cities, as well as the

private sector. The reservoir and its adjacent areas also have a long standing tradition of agricultural use, which consists of dairies, ranches and farms. The largest dairy farms in the nation are located near the Prado Dam basin. A cheese plant located in the City of Corona is considered one of the largest in the world. A detailed description of existing land uses and recreation facilities is given in appendix D of this volume.

Existing Flood Control Facilities

DAM EMBANKMENT

2-03 The existing dam is a compacted multi-zoned earth-filled embankment with a crest length of approximately 2,280 feet, and a height of about 106 feet above the original streambed. See plates 3 and 4 for a plan view of the dam embankment. The top of the embankment is 30 feet wide and paved with asphaltic concrete. The upstream face of the embankment has a slope of 1V on 3H for its lower 50 feet, and a slope of 1V on 2.5H for the remaining upper 56 feet. The downstream face of the embankment has a slope of 1V on 2.5H for its top 30 feet and 1V on 6H below elevation 495.0 (see pl. 5). The upstream slope is revetted with a layer of 12-inch stone over 6-inch bedding material and the downstream slope is covered with a 12-inch thick blanket of gravel.

OUTLET WORKS

2-04 The outlet works of Prado Dam is located near its right abutment. The outlet works consist of a 195-feet long intake structure, a 591-foot long double box conduit, and a 366-foot long rectangular concrete outlet channel.

a. The intake structure is formed by two gravity-type concrete walls and a reinforced concrete invert. The middle third of the intake structure is divided by five concrete piers into six bays for guiding flood water to the six control gates. A trash rack was installed in front of each bay and a 7-foot by 12-foot tractor gate was provided at the downstream end of each bay for control of outflows. A 90-foot long transition section joins the six gated chambers and two 5.5-foot-diameter conduits with the double box conduits downstream. The control tower including the control house is an integral part of the intake structure, and is located directly above the gate chamber. A 14-foot wide and 180-foot long concrete deck service bridge connects the control house to the top of the dam embankment.

b. Each of the double box conduits is 13.5 feet in height and 13.5 feet in width. A 5-foot diameter steel pipe with reinforced concrete encasement was provided underneath the double box conduits for a line to carry brine and industrial waste at the request of the Orange County Flood Control District.

2-05 The outlet channel consists of a 126-foot long open rectangular section, and a 200-foot long stilling basin. The rectangular section has a width of 31 feet, and wall heights ranging from 20 feet to 18.5 feet. The stilling basin has widths varying from 31-feet to 70-feet, and wall heights ranging from 18.5 feet to 33 feet. Downstream from the stilling basin is an 1,800-foot long trapezoidal channel capable of conveying 10,000 cfs.

SPILLWAY

2-06 The existing spillway structure, which is detached from the main embankment, was constructed through a bluff forming the east abutment (see pl. 4). The approach channel to the spillway was formed by excavation. The bottom width of the approach channel is 1,063 feet at invert elevation 530 feet and the side slopes are 1V on 2H. The downstream 85 feet of the approach channel near the ogee section has concrete gravity walls that range from 5 to 31 feet in height. The spillway control section is a reinforced concrete ogee, 13 feet high, with a crest length of 1,000 feet at elevation 543 feet (see pls. 6 and 7). The spillway channel is a reinforced concrete trapezoidal section, varying in width from 1,000 feet at the ogee crest to 660 feet at the lower end. The spillway channel is 1147 feet long. The spillway channel walls were designed as cantilever walls with an inclined face slope of 4V on 1H. At the downstream end of the spillway channel, a chute, 190 feet in length between elevation 522.4 feet and elevation 462.6 feet with a flip bucket at the end, terminates the spillway structure. To prevent undermining of the flip bucket, a concrete crib cutoff wall, about 92 feet in depth, was provided at the end of the spillway chute under the flip bucket.

DIVERSION STRUCTURE FOR SIDE DRAINAGE

2-07 The 273-foot long diversion channel is located adjacent to the outlet works on the downstream side of the right abutment (see pl. 3). The reinforced concrete rectangular channel has a width of 5 feet and a wall height of 5 feet, with a safety chain link fence on top of its walls. The inlet of the channel is supported by a gravity-type cutoff wall and the outlet of the channel was constructed monolithically with the west wall of the outlet works. The diversion channel was designed to convey runoff from a sand-mining plant and several small drainage areas on each side of the Corona Expressway near the abutment of the dam. About 200 feet upstream from the structure, an existing 42-inch corrugated metal pipe culvert was provided underneath the Corona Expressway by local interests.

DAM OPERATOR'S HOUSE

2-08 A residential building with double garage was constructed in 1940 by the Government for the dam operator who was required to live on the premises of the dam as a condition of employment. As a result of a policy change, this residential building has been vacated by the dam operator and subsequently removed; but the 700 square-foot woodframe double garage is still remaining and being used.

ACCESS ROADS

2-09 A paved access road is available from the Corona Expressway to the top of dam, the left abutment area, and the vicinity of the spillway. Additional unpaved access roads to various parts of the flood control complex have been developed over the years; some of these roads are vital for operation, maintenance, and inspection of the facility.

INSTRUMENTATION

2-10 For monitoring the condition of the existing earthfilled dam embankment, 38 settlement monuments and three settlement pipes were installed at various locations on Prado Dam. Twelve monuments are located on the slope of the dam 90 feet upstream from the centerline of the embankment, 15 are located on the centerline, and 11 are located on the berm 133 feet downstream from the centerline. Three settlement pipes are located at station 7+00 of the dam embankment: one on the centerline, and one each on the slopes 90 feet upstream and downstream from the centerline.

Present Condition of the Dam

2-11 Since its completion in May 1941, Prado Dam has adequately performed its authorized purpose of flood control. The structure is in excellent operating condition, but is in need of modifications; i.e., the spillway is undersized and the reservoir has insufficient capacity to control greater than a 70-year flood. The deficiency can be attributed to the increases in reservoir and spillway design rainfall and runoff sediment accumulation, and the increase in runoff to the reservoir due to urbanization over much of the valley since 1939.

The Flood Problem

STORAGE CAPACITY

2-12 As originally designed, the reservoir below the spillway crest elevation of 543 feet had a gross capacity of 217,000 acre-feet, of which 205,000 acre-feet was allocated for flood control, and the remaining 12,000 acre-feet was allocated for sediment storage for a 50-year period. Upon completion of the dam in 1941, survey of the reservoir indicated that it had a gross capacity of 222,840 acre-feet below the spillway crest elevation 543.0. A survey in 1979 shows 26,600 acre-feet of sediment has accumulated in the reservoir since 1941, and the remaining gross capacity is 196,240 acre-feet below elevation 543.0. The original flood control capacity has been depleted by about 9,000 acre-feet, and this capacity will continue to diminish as sediment continues to accumulate during the life of the project.

CRITERIA CHANGE

2-13 As a result of increases in design rainfall and runoff due to urbanization of the drainage area, the design volume of the Reservoir Design Flood (RDF) has been revised from 275,200 acre-feet to 415,800 acre-feet, and the design volume of the Probable Maximum Flood (PMF) has increased from 233,000 acre-feet to 1,543,000 acre-feet. Routing of the revised PMF through the reservoir could result in the existing dam being overtopped by 4.3 feet of water (elevation 570.3); therefore the existing dam embankment must be raised.

DOWNSTREAM CHANNEL

2-14 The existing Santa Ana River downstream from Prado Dam flows through the urbanized Orange County from Weir Canyon Road to the Pacific Ocean over a distance of approximately 23 miles. This reach of the river has been channelized by local agencies over the last decades by construction of a soft bottom channel with revetted side slopes and stabilizers at the selected locations. Although most of the channel reaches are adequate in size to convey a flood flow of more than 30,000 cubic feet per second, but its invert, side slopes, and bridge foundations are subject to severe erosions whenever the release from Prado Dam exceeds 5,000 cubic feet per second. The existing spillway with its crest at elevation 543 feet is capable of controlling only a 70-year flood; floods exceeding 70-year frequency would overtop the spillway and would cause severe damages to the downstream channel. The existing spillway crest must be raised to retain the design flood and provide the flood protection to downstream facilities.

The Authorized Plan

2-15 The flood control plan authorized by Congress is based on the plan recommended by the Los Angeles District of the U.S. Army Corps of Engineers, as described in the Phase I General-Design Memorandum on the Santa Ana River Mainstem Including Santiago Creek dated September 1980.

2-16 In the Phase I GDM, the proposed flood control improvement at Prado Dam included (a) raising the existing top of the dam from elevation 566 to 596 feet above the National Geodetic Vertical Datum of 1929; (b) construction of a new intake structure and outlet conduits; (c) modification of the spillway by widening from 1,000 to 1,300 feet; (d) construction of a new auxiliary PMF dike along the Santa Fe Railway from the existing spillway to Serfas Club Drive; (e) modification of a portion of the existing Highway 71 (Corona Expressway) to elevation 596; (f) construction of ring dikes to prevent flooding of the Corona Sewage Treatment Plant, the Alcoa Aluminum Plant, and the California Institution for Women; and (g) acquisition of rights-of-way or easements between the existing reservoir taking line and elevation 566.

2-17 The Phase I GDM recreation plan included four multi-use lakes for water-oriented recreation, including fishing, non-power boating and swimming. During the review period at the Office of the Chief Engineer, the question of developing multi purpose-lakes within the dry land reservoir was referred to the Office of Policy for review and comment. The determination by the Office of Policy was that there is no authority available to the Corps for construction of a lake. As a result of this consideration, the authorized plan included recreation as a project purpose, but the Los Angeles District was directed to prepare a reformulated recreation plan which will not include water-oriented recreation.

The Plan Recommended in this Report

DAM EMBANKMENT

2-18 Hydraulic routing of the PMF through a 1,000-foot spillway results in a maximum water surface at elevation 589.9 feet. Following freeboard, the top of dam embankment would be set at elevation 594.4 feet instead of 596 feet shown in the Phase I GDM. The debris pool would be at elevation 490 feet rather than elevation 500 feet as shown in the Phase I GDM.

AUXILIARY DIKE

2-19 Due to new development at the eastern end of the auxiliary dike, the alignment and design of the dike has been revised. The dike, approximately 1 mile in length, would begin on the southeast side of the spillway crest, and extend southeastward to just north of the Santa Fe Railroad, and then eastward to Serfas Club Drive. A floodwall with heights varying from 16 feet to one foot, having a total length of about 1,500 feet, would connect the dike and the high ground east of Serfas Club Drive (former Pomona-Rincon Road). A ramp with its top at elevation 590 would be provided at Serfas Club Drive.

INTAKE STRUCTURE AND OUTLET CONDUITS

2-20 A control tower with double 19-foot x 23-foot outlet conduits would be located between the dam embankment and the spillway. The two 800-foot long conduits would be constructed by open excavation and backfill method. Downstream from the conduits, a 270-foot long stilling basin and a riprap outlet channel approximately 1,800 feet in length would be provided to join the existing channel.

SPILLWAY

2-21 A recent spillway-embankment-optimization study indicates that the most economical design would be to maintain the existing spillway crest at its present length of 1,000 feet. The Phase I GDM contained a 1,300-foot-wide spillway crest length. Consequently, only the spillway walls would be raised and two new dikes would be provided at the entrance of the spillway for training flows in the approach channel.

The retaining wall shown in the Phase I GDM downstream from the spillway and on the north side of Riverside Freeway (Highway 91) would not be necessary.

CORONA EXPRESSWAY (HIGHWAY 71)

2-22 The existing road surface near the west abutment of the dam is at approximately elevation 566. Raising the top of the road at this location to elevation 594.4 feet would affect not only the Highway 71 bridge crossing the Santa Ana River, but also the interchange with Highway 91 south of Prado Dam. In order to minimize relocation costs, the high point of the modified highway at elevation 594.4 would be located approximately 2,200 feet north of the dam embankment. A new dike with its top at elevation at 594.4 would be provided along the east side of Highway 71 between the abutment of the dam and the high point. Modification of the bridge and interchange south of Prado Dam would be avoided.

INTERIOR DIKES

2-23 Diking of existing facilities would include the Corona Sewage Treatment Plant, California Institution for Women, the Alcoa Aluminum Plant, and the Corona National Housing Tract. Alignment of dikes has been refined to avoid interference with existing utilities and other improvements thus minimizing relocation cost. Each diked area would include an interior ponding area for storage of local runoffs. Dikes would have variable elevations along the top with a minimum elevation of 565 feet for an overflow structure.

CORONA NATIONAL HOUSING TRACT

2-24 Approximately 30 houses in the Corona National Housing Tract are located within the proposed reservoir taking line. The Phase I GDM recommended acquisition of these houses. Latest studies indicate flood prevention by diking (in lieu of rights-of-way acquisition) is feasible and a dike on the west and south side of the housing tract is recommended.

DEFERRED RECREATION PLAN

2-25 No site specific recreation plan is presented in this Phase II GDM due to the late appearance of local sponsors for recreation development. A supplemental GDM will be prepared at a future date to address the reformulated recreation plan, as directed in the authorization of the Phase I GDM. Appendix D presents a Resource Use Plan on which the reformulated recreation plan will be based.

Consideration of Other Alternatives

GATED SPILLWAY

2-26 A study was made of substituting a gated spillway in lieu of the ungated spillway. The study was conducted because a gated spillway might result in an overall reduction of construction costs, a reduction in flooding to properties on the perimeter of the reservoir during spillway flows, and a reduction in the construction period for the project. The results of the study are presented in an Information Paper, "Gated vs. Ungated Spillway Alternatives at Prado Dam," dated 10 February 1987. The study concludes that the increase in induced damages to downstream areas at the higher flood levels for the gated spillway results in an economically unattractive alternative; therefore, the ungated spillway was carried forward for design. In addition, subsequent to the completion of the Information Paper, an optimization of the spillway width versus embankment height indicates that maintaining the existing spillway width would have significant cost reduction in the spillway modification. The result of this optimization study further enhanced the economic superior of the ungated spillway. The Information Paper with a summary and recommendation is present in Appendix A, entitled Gated Spillway Study.

Related Studies and Reports

2-27 Since authorization of the flood control project under the Water Resources Development Act of 1986, studies pertaining to the existing oil and gas leasehold interests, and water supply and conservation at Prado Dam were completed. A summary and reference to the report by the Bureau of Land Management and the report by the Corps of Engineers for Orange County are provided in the Main Report.

III. PROJECT FEATURES

General

3-01 Due to the late appearance of local sponsors for recreation development, the current report recommends flood control features only. Detailed description of project features such as the dam embankment, the auxiliary dike, outlet works, spillway, interior dikes, etc., are presented in the following paragraphs.

Dam Embankment

3-02 In order to enlarge the reservoir capacity, the dam embankment must be raised and extended in length to the area of the existing spillway. An addition of 28.4 feet of earthfill embankment on top of the existing dam would be accomplished by first removing the top 8 feet of the embankment and the 12 inches of gravel on its downstream slope. Compacted fill would then be placed on the scarified surface of the downstream slope, and 24 inches of stone protection over 9 inches of bedding and 6 inches of filter would be placed on the upstream slope of the raised embankment. A typical section of the dam embankment is shown on plate 5. Extension of the embankment from the existing dam to the spillway would be about 800 feet in length and approximately 30 feet above the existing ground surface. The cross section of extension embankment would be identical to the raised embankment, and would be constructed at the same time with the raised embankment to form a homogeneous section after the completion of the outlet works. The top of the raised embankment between station 0+00 and station 4+70 would be offset approximately 50 feet south of the remaining part of the dam to allow for construction of a turnaround and a vehicular access ramp from the top of dam to the base of the intake tower. The main access to the top of dam, the outlet works, and the spillway would be provided from the existing Highway 71.

Auxiliary Dike

3-03 The general ground elevation of the area southeast of the spillway is below elevation 594.4 feet. In addition, the existing main line of Santa Fe Railway with its track at elevation 560 feet cuts across the southern edge of the reservoir. The Probable Maximum Flood water surface at elevation 589.9 feet would escape control by flowing over the lowland southeast of the spillway or through the opening for the railroad tracks underneath Highway 91 (Riverside Freeway). The auxiliary dike for controlling the spillway design flood would be provided from the southeastern part of the spillway and extend along the northern side of the railroad track. The recommended alignment would be on high ground along the edge of reservoir without crossing the Santa Fe railroad tracks. An access road would be provided to the dike from Serfas Club Drive. The location of the dike and its profile are shown on plates 11 and 12, respectively.

3-04 The compacted earthfill dike extending from the south side of the spillway to the west side of Serfas Club Drive would be approximately 5,370 feet in length. The top width of the dike would be 20 feet at elevation 594.8 feet. The maximum height of the dike above the existing ground would be approximately 74 feet, with an average height of about 30 feet. The dike embankment would have side slopes of 1 vertical on 2.25 horizontal, and would have slope revetment consisting of 24-inch stone over 9 inches of bedding material and 6 inches of filter on the reservoir side. The embankment would consist of homogeneous material. The foundation treatment would consist of stripping 18 inches of the entire area underneath the embankment, and constructing a cutoff trench with a 15-foot-wide base and a depth varying from 4 to 10 feet. Four gated culverts with sizes of 36 inches (two), 72 inches, and 84 inches in diameter would be provided under the embankment for conveyance of runoff from four drainage areas located south of the railroad track.

3-05 A concrete floodwall would be provided along the north side of the railroad track from a point approximately 300 feet west of Serfas Club Drive, where the eastern end of the dike is located, to a point 1,200 feet east of Serfas Club Drive where the existing ground is at elevation 595. The recommended floodwall would be constructed within a 20-foot wide dedicated easement located approximately 100 feet north of the existing railroad track. Wall heights would range from 16 feet at the western end to 2 feet at the eastern terminus. A 40-foot wide paved ramp with its top at elevation 590 feet and a maximum grade of 8 percent would be provided over the existing Serfas Club Drive. Details of the floodwall and ramp are shown on plate 11. A 72-inch diameter culvert with a length of 960 feet would be provided underneath the floodwall for conveyance of local surface runoff to Prado Reservoir.

Outlet Works

3-06 The recommended outlet works would be designed to release up to 30,000 ft^3/s an increase of more than three times the capacity of the existing outlet works. Consequently, a new outlet structure would be provided between the eastern end of the existing embankment and the spillway. The existing outlet works would be used for diversion and control of water during construction of the proposed outlet works and would be plugged with concrete throughout their entire length upon completion of the new outlet structure. The proposed outlet works would consist of an approach channel, a regulating structure, the outlet conduits, a stilling basin, and an outlet channel (pls. 8 and 9). Full details of the outlet works are contained in appendix C.

APPROACH CHANNEL

3-07 The approach channel would have a base width varying from 540 to 140 feet with its invert at elevation 465. Due to the existing ground condition surrounding the intake structure, a 50-foot high wingwall would be constructed on each side of the channel. The approach channel would be unlined, and stone toe protection would be provided for the wingwalls and the intake structure.

REGULATING STRUCTURE

3-08 This feature would consist of two intake structures and a transition structure. Each intake structure would house a trash rack, three intake passageways with a bulkhead slot and a slide gate, plus a gated low flow channel with invert at elevation 470. Each service gate would be 9.5 foot wide by 14.75 feet high and would be operated from a gate room above the passageway. Above the gate room would be an access tower with an elevator from the gate room to the mechanical deck where a control room would be housed. A 180-foot-long access bridge with the deck at elevation 594.4 feet would be provided for vehicular access between the access tower and the dam embankment. Details of the access bridge are shown on plate 10.

3-09 The transition structure would combine the flows from the three gated passageways into a single flow before discharging into the two 23-foot-high by 19-foot-wide conduits. The low-flow bypass would also have a downstream outlet within the limit of the transition structure.

OUTLET CONDUIT

3-10 Two 600-foot-long rectangular conduits would be provided just downstream from the transition structure for the conveyance of 15,000 ft^3/s each. The conduits would have an internal dimension of 23 feet in height and 19 feet in width; the invert slope of the conduits would be 0.0135.

STILLING BASIN

3-11 Downstream from the conduits, a stilling basin would be provided to dissipate the hydraulic energy of the floodwater before discharging into the outlet channel. The 270-foot-long concrete stilling basin would have a total width, including a 5 foot divider wall, varying from 43 feet to 77 feet. Exterior wall heights would range from 23 feet to 49 feet, while the top of the divider wall would be at the maximum water surface elevation. Dentates for energy dissipation and slots for installation of stoplogs during maintenance would be provided in the stilling basin structure.

OUTLET CHANNEL

3-12 The excavated channel extending from the stilling basin to a modified existing drop structure at (sta. 49+57 to sta. 50+00) would be approximately 4,800 feet in length. The outlet channel would have revetted side slopes and an unlined invert, with widths varying from 77 feet to 200 feet at the downstream terminus. The alignment of the outlet channel was selected to avoid relocation or modification of the existing Corona Expressway bridge.

Spillway

3-13 The existing concrete lined spillway would remain and be utilized for the flood control project recommended in this report; however, modification of certain parts of the existing spillway structure would be necessary. The existing concrete ogee section would be raised from its crest at elevation 543 feet to elevation 563 feet by the addition of a concrete cap. In order to form a monolithic structural section, a portion of the invert would be removed and reconstructed. Spillway walls would be extended by the addition of a concrete vertical or inclined wall depending on the location and terrain condition in the vicinity of the existing structure. A model study of the spillway conducted by the Waterways Experiment Station at Vicksburg indicated that floodwater flows at the approach of the spillway would be erratic unless training dikes are provided on both banks of the approach channel. These dikes would be extended 300 feet upstream from the spillway crest and, in general, would be earthfill structures with 18 inches of grouted stone revetment. On the east side of the spillway, the top width of the dike would be 16 feet at elevation 589.9, and side slopes would be revetted with 18 inches of grouted stone. Due to the location of the west dike near the entrance of the proposed outlet works, the top of dike would be limited to elevation 553; and a concrete training wall would be provided between elevations 553 and 589.9 (pl. 4).

3-14 In order to avoid inducing additional loads and surcharging the existing gravity wall on each side of the spillway, the maximum 28.9-foot high retaining wall would be located at least 40 feet away from the gravity wall. The alignment of the retaining wall was selected to minimize its length. The height of the retaining wall would vary in

accordance with the computed water surface over the spillway. The area between the existing gravity wall and the retaining wall would be paved with 6 inches of concrete for protection against erosion of the retaining wall footing.

3-15 Extension of the spillway walls downstream from the retaining wall would be accomplished by paving the existing 5-foot-wide berm and side slopes above the top of the existing spillway with 8 and 6 inches of reinforced concrete, respectively. A subdrainage system would be provided beneath the concrete side slopes for collecting and releasing any accumulated subsuface water.

3-16 The downstream portion of the spillway wall extension between station 20+20 and station 21+20 would be provided by constructing a levee with a top width of 8 feet and a maximum height of 4 feet (pl. 7). A concrete slab would be provided between the top of levee and the top of the existing wall.

Dike at Corona Expressway

3-17 The existing Corona Expressway (Highway 71) is located along the western edge of the reservoir area of Prado Dam. The top of road elevation varies from 566 feet at the abutment with Prado Dam to 559 feet at a point approximately 3,000 feet north of the abutment. The probable maximum water surface behind the dam would be elevation 589.9, thus the roadway would have to be raised approximately 25 feet to contain the Probable Maximum Flood. Raising the top of the road at the axis of the dam to elevation 594.9 feet would affect not only the highway bridge crossing the Santa Ana River, but also the interchange with Highway 91 (Riverside Freeway) downstream from Prado Dam. In order to reduce relocation and construction costs, the high point of the highway at elevation 594.9 would be located approximately 2,200 feet north of the dam embankment (pl. 13). A proposed dike with its top at elevation 594.9 would be provided along the east side of the existing Corona Expressway between the abutment of the dam and the high point. Modification of the bridge and the interchange south of Prado Dam would not be necessary.

3-18 Construction of the dike would require prior modification of the highway. A detour would be necessary for the heavily used highway during construction of the dike (pl. 14). A three-stage construction procedure (pl. 15) would be required. In the first stage, the lower portion of the dike would be constructed to an elevation which could be utilized for detour of vehicular traffic during modification of the highway. The second stage would involve raising the highway at a gentle ascending slope of 2.56 percent from elevation 566 in the vicinity of the dam to elevation 594.9 at station 23+00 where the roadway would then begin a descending slope of 3.44 percent until the road surface meets

the existing road elevation at station 38+50. The last stage of construction would include the upper portion of the dike between the top of detour and elevation 594.9.

3-19 The dike would be approximately 2,130 feet in length, and its slope surface on the reservoir side would be revetted with 24 inches of stone over 9 inches of bedding and 6 inches of filter material. The embankment would be a homogeneous section with 1V on 2H side slopes and a top width of 15 feet at elevation 594.9.

Dike at Corona Sewage Treatment Plant

3-20 The existing sewage treatment plant is owned by the City of Corona and is located on 49 acres of reservoir land owned by the U.S. Government. The land has been leased to the city since 1967. The treatment facility, which consists of sedimentation tanks, aeration tanks, digesters, and the control buildings, occupies approximately 20 percent of the land; and sludge drying beds occupy most of the remaining space. The treatment facility and about half of the drying beds are below elevation 566.

3-21 Consideration was given to floodproofing the facility. Flood proofing would require construction of floodwalls up to 16 feet in height with six sets of stoplogs for openings at road crossings. The total length of the floodwalls would be approximately 1,100 feet, and the stop logs at the road openings would vary from 8 to 15 feet in height, and 30 to 70 feet in width. Another consideration was to replace some of the floodwalls and road openings with earthfilled dikes and ramps. This alternative would still require 610 lineal feet of wall, two sets of stoplogs, and 2,100 feet of dikes and ramps. These alternatives were not adopted due to their adverse impacts on the daily operation and land usage of the facility.

3-22 The recommended plan (pls. 16 and 17) is to construct a dike on the outside boundary of the facility. The dike would be approximately 3,810 feet in length, and its maximum height would be 53 feet above the existing ground surface. The top of dike would be 15 feet in width, and the side slopes of the dike would be 1V on 2.25H. The reservoir side of the slopes would be revetted with 18 inches of stone over a layer of filter cloth, while the landward side would be landscaped with native shrubland species. For interior drainage, an 17.6-acre-foot ponding area between elevations 526 and 537.6, and a 36-inch culvert with a flapgate at the outlet structure would be provided. The dike would provide a 190-year level of protection for the sewage treatment plant.

Dike at Alcoa Aluminum Plant

3-23 The privately owned Alcoa Aluminum Plant is located just outside of the existing rights-of-way in the southeastern part of the reservoir. The entire plant (plus other privately owned development) is located within the proposed reservoir taking line at elevation 566. Studies

indicate that it would be more economical to construct a dike around the aluminum plant and other properties than to acquire these properties for flood control purposes.

3-24 The recommended dike would be located on Government land and would be adjacent to the existing Smith Avenue and Rincon street. The alignment of the dike was selected to minimize impacts on existing facilities such as streets, utilities, sludge drying beds, and other industrial and commercial development. Nevertheless, the proposed dike would have to cross over Smith Avenue, Butterfield Drive, Rincon Street, and Auburndale Street. The dike would be 5,550 feet in length, and its top would vary in elevation between 566.0 and 569.8 in accordance with the freeboard design. This design would provide 190-year level of protection (pl. 18). The dike (pl. 19) would have a top width of 15 feet, and a maximum height of 30 feet above the existing ground surface with an average height of approximately 20 feet. The reservoir side of the slopes would be protected with 18 inches of stone over a layer of filter cloth. A ponding area with a storage volume of 55.5 acre-feet between elevations 544.7 and 550.7, plus a 36-inch culvert with a flap gate at the outlet structure, would be provided for the interior drainage behind the dike. Road crossings at Butterfield Drive, Rincon Street, and Auburndale Street would be modified. Temporary detours would be provided as necessary during construction.

Dike at Corona National Housing Tract

3-25 The housing tract is located within the city limits of Corona, adjacent to the southeastern portion of the Prado Dam reservoir (pl. 20). Approximately 30 houses along Meadowview Street and Greenbriar Avenue are located within the proposed taking line at elevation 566. Acquisition of these houses would be costly and would have adverse social and economical impacts on the community. The recommended alternative is to provide a dike along the southwestern side of the tract and a floodwall on the northwestern boundary of the tract, where inadequate space would be available for the construction of a dike. The dike, with a top width of 15 feet, would be about 1,870 feet in length and its maximum height would be 24 feet, with average height of approximately 17 feet above the existing ground surface. The reservoir side of the 1V on 2.25H side slopes would be revetted with a 18-inch layer of stone and a layer of filter cloth. A ponding area having a storage capacity of 11.1 acre-feet between elevations 548 and 555.6 would be provided behind the dike. For draining the ponding area, a 36-inch diameter culvert with a length of 104 feet and a flap gate at its outlet structure would be provided. The landward side of the dike would be planted with native grass. The entire dike would be located within the existing reservoir land.

3-26 The reinforced concrete floodwall would be about 1,080 feet in length, and approximately 6 feet above the existing ground surface.

Dike at California Institution for Women

3-27 The institution is under the jurisdiction of the State of California and is located on a 12.5 acre site adjacent to U.S. Government land in the northern part of Prado Dam reservoir. Approximately by 75 percent of the site is below the proposed taking line at elevation 566; acquisition and relocation of the existing facility would be economically and socially infeasible.

3-28 The recommended plan includes construction of a dike on mostly existing reservoir land along the western and southern border of the facility. A ponding area having a storage capacity of 16.3 acre-feet between elevations 551.0 and 557.6 would be provided with a 36-inch diameter culvert for draining the ponded water into the reservoir (pl. 21). The dike on the west side of the institution would be approximately 2,860 feet in length, and the top of the dike elevation would range between 566 and 568.6. The dike along the southern part of the facility would be 2,910 feet in length of which 1,130 feet would be located on privately owned land to be acquired. The elevations on top of dike would vary from 566.0 to 570.7, depending on the exposure to the reservoir and computed wave height (pl. 22). This design would provide protection against floods having a frequency of up to 190 years. Both dikes would have a top width of 15 feet and side slopes of 1V on 2.25H. The reservoir side of the slope would be protected by an 18-inch-thick riprap over a layer of filter cloth.

Access Roads

3-29 Vehicular access to the top of the dam embankment, the outlet structure, and the spillway would utilize the existing Corona Expressway and the existing entrance road to the dam at its left abutment (pl. 3). The top of the dam embankment would be paved with 2 inches of asphaltic concrete so that the road could be used under all weather conditions. An existing access road located between the dam embankment and the spillway would be realigned to an east/west direction to avoid interference with the embankment and outlet works. This access road would also be paved with asphaltic concrete.

3-30 Access to the top of the dike along the Corona Expressway would be provided at station 23+00 where the elevation at top of the dike would be equal to the road surface of the highway. A gated entrance from the expressway to the top of the paved dike would be provided at station 23+00.

3-31 Riverside Freeway and Serfas Club Drive would provide the access to the eastern end of the auxiliary dike along the Santa Fe Railroad. A gated access ramp to the top of the dike would be provided on the west side of Serfas Club Drive. The 20-foot-wide top of the dike would be paved with 2 inches of asphaltic concrete and be utilized as an access road. A turnaround near the spillway would be provided.

3-32 A gated vehicular access to the top of the ring dikes would be provided, in general, at the intersection of the dike with the public street where the top of the dike and street surface would be the same. For the dike at Corona sewage treatment plant, the access road would be from Butterfield Drive and Clearwater Drive. Access to the top of the dike at the Alcoa Aluminum Plant would be provided at Butterfield Drive, Rincon Street, and Auburndale Street. The dike at the Corona National Housing Tract would not cross any public street. In order to provide vehicular access to the dike, an access road with its top at elevation 568 would be constructed between Auburndale Street and the top of dike. Vehicular access to the dike at the California Institution for Women would be from Cucamonga Avenue. A gate would be installed on top of the dike at station 72+00, and the top of the south dike would be paved for all weather use. Access to the dike along the west side of the institution would be possible by construction of a road around the west side of the hill between station 46+00 and station 34+00. The minimum elevation of this 1,250-foot long road would be elevation 559.0. Construction of an all weather access road to the west dike would require acquisition of additional rights-of-way.

Flood Emergency Plans

3-33 The operation of Prado Dam would not be modified until the Santa Ana River channel downstream from Prado Dam is ready to convey the design release of 30,000 ft^3/s. During construction, the existing outlet works would be fully utilized to minimize the volume of impoundment behind the dam and the spillway crest would not be raised prior to completion of the outlet works. The construction of the outlet works would be staged so that the existing dam is completely operational. The outlet works would be constructed in three stages so that the existing ground or compacted backfill between the embankment and the spillway would be at the minimum elevation of 566. The stages of new outlet construction are shown in appendix C. Gates or bulkheads would be installed in the new outlet conduit before Stage II construction is to start. The existing dam, including all its facilities, is capable of controlling a flood up to 70-year frequency with the maximum water surface at the spillway crest elevation 543. The existing Flood Emergency Plan, dated November 1985, would be utilized for downstream evacuation in the event of a major flood. A separate flood emergency plan for the period during construction is not necessary.

Reservoir Clearing

3-34 The existing Prado Dam has been operated successfully for flood control since its completion in 1941. Floatable debris in the reservoir area is limited to shrubs and small fallen trees. The debris pool would be established at elevation 490 feet and the available amount of floatable debris at the new outlet works is not expected to increase significantly. However, in order to assure that floatable materials do not block floodflows into the proposed outlet structure, the immediate upstream area within 500-feet of the outlet works would be cleared

(approximately 10 acres). Clearing would be limited to the removal of floatable organic material of sufficient size to obstruct the outlet works. In addition, any floatable structures or materials located below elevation 563 such as abondoned barns or unused haystacks would be secured in place or removed from the reservoir area.

Hydrologic Facilities

RESERVOIR WATER SURFACE RECORDING SYSTEM

3-35 A 24-inch diameter float well will be constructed within the outlet works control tower. A tape-float-pulley assembly will be installed within this float well. A strip-chart water surface recorder will be installed to automatically record the float well water surface elevation. A digital readout display will be attached to the recorder to provide the latest recorded measurement.

RESERVOIR STAFF GAUGES

3-36 A series of staff gauge boards will be installed along the upstream face of the dam. The boards will be graduated in 0.10 foot increments. Each staff gauge board will be at least 5 feet high and attached to galvanized steel channel set in concrete. Each staff board should be installed so as to be readable from the top of the dam. The elevation of these staff gauges should be adjustable.

OUTLET GATE RECORDERS

3-37 Each outlet service gate will have an automatic recorder to document all gate movements. These recorders will monitor gate settings and make a permanent record of them. They will be connected to the gate control mechanisms and the radio telemetry equipment. The recorders should be automatically activated each time a gate control switch is activated and a recording of the new gate setting with the date and time will be made. This information will then be recorded on paper and transmitted to the District Office via the radio telemetry equipment.

PRECIPITATION STATIONS

3-38 Tipping-bucket rain gauges will be installed at the control house and at the stream gauging station downstream of the dam. In addition, rain gauges will be installed at the following locations to provide better coverage over the drainage area to improve runoff forecasting: USGS stream gauge 11054000 on Mill Creek, USGS stream gauge 11055500 on Plunge Creek, USGS stream gauge 11066460 on the Santa Ana River, USGS stream gauge 11055800 on City Creek, Lytle Creek Fire Station, Winchester NWS precipitation station, and March Air Force Base NWS precipitation station. The tipping-bucket gauges will accumulate .01 inch of rainfall before each tip.

STREAM GAUGING STATION

3-39 The existing USGS stream gauging station, "Santa Ana River below Prado Dam," No. 11074000, will be the gauging station used to measure outflow from the revised Prado Dam. However, some improvements are required to make this station fully operational. The station's control section will be repaired or replaced and extended so that it reaches across the entire width of the river. It will be shaped so that low flows are trained towards the stilling well. The existing cableway will be relocated to a position directly over the new control section in order to provide access for instream measurement during high flows. The cable of the existing cableway is worn out and will be replaced with new cable. A digital readout display will be attached to the recorder to display the latest recorder measurement.

MONUMENTED SEDIMENT RANGES

3-40 The existing index range lines within the reservoir area should be updated to match the new project boundaries. They should be surveyed near the completion of the new project construction in order to update the reservoir's elevation storage relationship. They will be used to provide an indication of the amount of sediment deposition occurring in the reservoir during the project life and to help determine the need for additional topographic mapping.

RADIO TELEMETRY EQUIPMENT

3-41 A "remote terminal unit" (RTU) entirely compatible with the existing Los Angeles District's telemetry system will be installed at both the reservoir water surface level gauge house and the downstream gauge house. In addition, RTU's will be installed at the following locations to provide a better coverage over the drainage area to improve runoff forecasting: USGS gauge 11054000 on Mill Creek, USGS gauge 11055500 on Plunge Creek, USGS gauge 11066460 on the Santa Ana River, USGS gauge 11055800 on City Creek, Lytle Creek Fire Station, Winchester NWS precipitation station, and March Air Force Base NWS precipitation station. Each RTU will include a power supply, hydrologic instrument interface, a shaft interface to connect to the water surface recorder (where applicable), programmable micro-computer control, radio transceiver, and antenna. These RTU's will transmit the gauged information to the District Office via a radio repeater station. AC power will be installed at all gauge houses that currently do not have it.

Relocation

3-42 Construction of the proposed dam embankment and outlet works would affect an existing 30-inch high pressure natural gas transmission pipeline along the downstream slope of the dam embankment, a drainage structure in the west abutment, power and telephone lines along the south side of the embankment, and a 3-inch distribution gas line near the east abutment of the dam (pl. 3). Raising the embankment to

elevation 594.4 would place about 20 feet of fill over approximately 400 feet of the existing 30-inch gas line owned by Southern California Gas Company, therefore, the pipeline would be encased in concrete. Near the east abutment of the dam, approximately 500 feet of the existing 30-inch gas line would be exposed during the excavation for the outlet works. Temporary support of the pipeline would not be feasible; because the pipeline would be approximately 100 feet above the invert elevation of the outlet works. The recommended solution is to relocate the pipeline to avoid interference. The drainage structure would remain but a concrete cover would be provided. The power and telephone lines, and the 3-inch gas line would be relocated.

3-43 In order to prevent design floods from escaping the reservoir by flowing over the existing Corona Expressway at elevation 566, the Expressway would be raised to elevation 594.8 feet.

3-44 The auxiliary dike, with its top elevation at 594.9 feet, would cross the existing Serfas Club Drive at approximately elevation 583.5. The recommended plan is to raise the road to elevation 590 which is the maximum water surface of the Probable Maximum Flood.

3-45 Construction of the interior dike at the Corona Sewage Treatment Plant would affect Clearwater Drive, which is the only entrance road to the sewage treatment plant. The road surface would be raised from approximately elevation 540 to elevation 566.

3-46 The proposed interior dike at the Alcoa Aluminum Plant would cross Butterfield Drive, Rincon Street, and Auburndale Street. Providing a flood gate of up to 30 feet in height at the road crossing would not be feasible, therefore ramps from the existing road surface to the top of dike are recommended. However, existing utilities (under the street surface) such as water, sewer, and gas lines would require protection, modification, or relocation.

Materials and Material Sources

3-47 Approximately 3.5-million cubic yards of embankment materials would be required for the construction of the dam, the auxiliary dike, modification of Highway 71, and interior dikes. These materials would be obtained from the borrow areas as designated on plate 2. Riprap stone of various sizes would be obtained from qualified commercial sources in the proximity of the project. Water would be obtained from the existing supply system in the basin area.

Esthetic Treatment

3-48 Upon completion of the dam embankment and the auxiliary dike, the downstream embankments would be stained with a chemical staining process and/or would utilize rock and/or gravel of varied size, color and texture. The interior dikes around the Corona Housing Tract and Corona

Sewage Treatment Plant on the landward side of the embankment would be seeded with forbs and grasses. Construction sites and borrow areas would also receive esthetic treatment to compensate for adverse effects of construction on the land.

Disposal Sites

3-49 Construction of the modifications to the Prado Dam would produce large quantities of organic, inorganic, and unsuitable construction materials which must be disposed of in the manner and areas specified so that the project site would be restored after completion of construction.

3-50 Organic materials, trees, shrubs, and abandoned timber structures, would be disposed of by hauling to a commercial site to be furnished by the local sponsoring agency. Topsoil containing organic material would not be disposed of at a commercial site, but would be stockpiled and spread on embankment slopes or borrow areas as a part of site restoration. Disposal of these materials by burning or burying at the project site would not be permitted. Inorganic materials would include, but are not limited to, broken concrete, rubble, asphaltic concrete, metal, and other types of construction materials. The volume of these materials would be rather small in comparison with the volume of embankment material to be removed from the borrow sites; therefore, there should be more than sufficient space for disposal of these materials at the borrow sites. The quantity of unsuitable excavated material from construction of the proposed facilities is difficult to predict, because it depends on the foundation formation at the site of the borrow area and other structures. The unsuitable material would also be disposed of at the borrow sites.

3-51 In disposing of inorganic and unsuitable construction materials at the borrow sites, the objective would be to restore the terrain of the borrow areas to their original appearance as much as possible. Inorganic materials would be placed in pits or below adjacent ground surfaces, and would be covered with a minimum of one foot of stripped material. Mounds or piles of disposed material at the site would not be allowed.

Deferred Recreation Development

3-52 Preparation of a site specific cost shared recreation plan has been deferred to a future date. A supplemental GDM will be prepared in the near future to address the reformulated recreation plan, as directed in the authorization of the Phase I GDM. During the early stages of planning for the Phase II GDM, no appropriate local sponsor indicated a willingness to participate in recreation development. As a result of this, the Resource Use Plan (appendix D) was prepared, on which future site specific recreation features would be based. In late 1987, however, as a result of changes in local administrations and recreation

needs being perceived as a higher priority, several local sponsors indicated a strong interest in recreation. In November of 1987, letters of intent were received from the City of Corona, the County of San Bernardino, and the County of Riverside. Due to this late appearance of local sponsors for recreation development, it was not possible to present a re-formulated plan in this report. The supplemental GDM and SEIS will reinstate the recreation component.

IV. HYDROLOGY

Introduction

4-01 This section presents a brief description of the Prado Dam drainage area, along with a presentation of design discharges, water surface elevations, and other pertinent information for the recommended project. More detailed information on the development of the hydrology is presented in Volume 7 of the Phase II General Design Memorandum for the Santa Ana River Mainstem including Santiago Creek.

General

4-02 The Santa Ana River Basin above Prado Dam (fig. IV-1) covers an area of approximately 2,255 square miles, excluding a closed area of about 32 square miles tributary to Baldwin Lake. The Santa Ana River Basin boundaries above Prado Dam are also shown in figure IV-1. Approximately one quarter of the basin is within the rugged San Gabriel and San Bernardino Mountains. Most of the remaining area is in valleys formed by the broad alluvial fan surfaces along the base of these mountains. Numerous low hills rise above the alluvial fan surface, and include a range of hills north of San Bernardino; the Crafton Hills east of Redlands; the Jurupa Mountains north and west of Riverside; the Box Springs Mountains and Badlands east of Riverside; and the Chino Hills northeast of Anaheim. In general, the mountain ranges are steep and sharply dissected. The San Bernardino Mountains are the source of the Santa Ana River and two of its principal tributaries, Bear and Mill Creeks. Lytle Creek, the largest tributary originating in the San Gabriel Mountains, is in the northwest corner of the watershed. The San Jacinto River has its origin in the San Jacinto Mountains southeast of Beaumont. The Santa Ana River has an average gradient of about 240 ft/mi in the mountains and about 20 ft/mi near Prado Dam. The average gradient of its tributaries is about 700 ft/mi in the mountains and about 30 ft/mi in the valleys. The mountainous areas are expected to remain largely undeveloped during the project life. The valley areas above and below Prado Dam are presently partially urbanized and are

expected to be completely urbanized at the end of project life. Two major Corps flood control dams are located in the Santa Ana River Basin: Prado Dam and San Antonio Dam. Other existing flood control improvements have been constructed by the Corps of Engineers and other local agencies. These improvements include channelization, debris basins, storm drains, levees, stone and wire-mesh fencing, and stone walls along the banks of stream channels. The principal existing water conservation improvements are spreading grounds and reservoirs. More than 100 water conservation and recreational reservoirs exist within the basin, and have storage capacities ranging from 5 to about 182,000 acre-feet.

4-03 Precipitation characteristically occurs in the form of rainfall, although in the higher elevations some falls as snow. In general, the quantity of preciptiation increases with elevation. The mean seasonal precipitation for the basin, which averages about 20 inches, varies from about 10 inches south of Riverside to about 45 inches in the higher mountain areas. Nearly all precipitation occurs from December through March. Rainless periods of several months during the summer are common.

4-04 Streamflow, which is perennial in the canyons of the Santa Ana River and in the headwaters of most tributaries, is generally also now perennial in the valley sections due to increased urbanization and the discharge of wastewater effluent into the river. Streamflow increases rapidly in response to effective precipitation. High-intensity precipitation in combination with the effects of steep gradients and possible denudation of hillsides by fire results in intense sediment-laden floods, with some debris in the form of shrubs, trees and boulders. Deposition of sediment occurs when flows reach the valley where stream gradients flatten. The urbanization of the valley areas of the Santa Ana River Basin makes the basin more responsive to rainfall. Hence, the same rainfall occurring over an urbanized part of the basin will generate higher peak discharges with a shorter peaking time and a greater volume than if it occurred over the natural basin.

Design Criteria

4-05 The recommended plan is to raise Prado Dam from elevation 566 feet NGVD (National Geodetic Vertical Datum) to elevation 594.4 feet and construct new gated outlets with the capacity to release up to 30,000 ft^3/s outflow. The spillway crest will be raised from elevation 543 feet to elevation 563 feet. The enlarged Prado Dam and Reservoir would provide a total storage allocation below spillway crest of about 362,000 acre-feet, including a 70,000 acre-foot, 100-year sediment allowance. Prado Dam will be able to control the future Standard Project Flood (SPF) inflow of 275,500 ft^3/s to below elevation 566 and a maximum outflow of 30,000 ft^3/s. The 30,000 ft^3/s outflow between elevations 563 and 566 feet NGVD is a combination of spillway flow and controlled outlet discharge. The duration of the critical volume (that volume which generates the peak water surface elevation) is about 2 days, and is about a 200-year event.

4-06 The reservoir design flood (RDF), which results in a spillway crest water surface elevation of 563 feet, is equal to 92 percent of the SPF future condition hydrograph with a peak discharge of 254,000 ft^3/s, and a 4-day volume of 415,800 acre-feet. The duration of critical volume (about 380,000 acre-feet) is about 2 days. The frequency of the event that produces this volume is about 190-year. The RDF routing is shown in figure IV-2. Design flood peak discharges for various concentration points along the Santa Ana River are shown in figure IV-3. The initial water surface elevation for the SPF and RDF routings is elevation 490 feet (top of debris pool). The appropriateness of this elevation is manifested in the water control plan for Prado Dam. The water control plan requires the release of floodflows to draw down the reservoir storage to the top of the debris pool in preparation for the next flood event.

4-07 Risk is defined as the probability that one or more events will exceed a given flood magnitude within a specified period of years. In other words, risk enables a probabilistic statement to be made about the chances of a particular location being flooded when it is occupied for a specified number of consecutive years. For example, if a project is designed to protect against a 100-year flood, during any 100-year period, there is a 63 percent risk that one or more floods will occur that exceeds the design level. The following is the results of the risk analysis at Prado Dam:

Period of Time (years)	Project Design Level Annual Exceedance Frequency (percent)	Risk of Exceeding Design Level (percent) One or More Floods	Risk of Exceeding Design Level (percent) Two or More Floods
10	approx. 0.5	5	0
25	approx. 0.5	12	1
50	approx. 0.5	22	3
100 (project life)	approx. 0.5	39	9

From the results listed above for the 100-year project life, a 39 percent risk exists that one or more floods will exceed the project design level of about 200 years. To illustrate, if 100 projects designed to protect against a 200-year flood during any 100 year period, 39 of the projects will experience one or more floods exceeding the design level.

V. HYDRAULIC DESIGN

General

5-01 The hydraulic design of Prado Dam is based on approved design practice and theoretical analysis set forth in the Waterways Experiment Station's Hydraulic Design Charts, EM 1110-2-1603 Hydraulic Design of Spillways, and appropriate Engineering Technical Letters, and other accepted references. In addition, results of a physical hydraulic model study of the Prado Dam spillway, spillway approach, and downstream conditions were utilized in the design.

5-02 The dam modification will provide sufficient capacity to (a) contain a Reservoir Design Flood (RDF) with a peak inflow of 254,000 ft^3/s and a 4-day volume of 415,800 acre-feet, reduce the standard project flood (SPF) from a peak inflow of 275,500 ft^3/s to a maximum outflow of 30,000 ft^3/s through a combination of spillway flow and regulated outlet discharge; (b) pass the spillway design flood, which is the probable maximum flood (PMF), with adequate freeboard; and (c) retain the 100-year sediment accumulation of 70,000 acre-ft.

Reservoir Area and Capacity

5-03 The area-capacity curve for Prado Reservoir was developed from a July-August 1979 survey. The sediment allowance of 70,000 acre-ft in the 1975 Review Report was determined to be adequate for final design. The anticipated sediment accumulation was distributed in the reservoir between the reservoir bottom and the spillway crest using the empirical area reduction method formulated by Whitney M. Borland and Carl R. Miller. A description of this method is presented in EC 1110-2-241, Draft Sedimentation Manual. The resulting area-capacity curve is shown in figure V-1. The net capacity of the reservoir will be zero at elevation 480.0, 292,000 acre-ft at spillway crest (elevation 563.0), and 659,000 acre-ft at the maximum water surface (elevation 589.9). The reservoir area will be 10,250 acres at spillway crest and 17,500 acres at the maximum water surface elevation.

Debris Pool

5-04 A debris pool is necessary at Prado Dam to protect the outlet works. Specifically, the debris pool must satisfy two design objectives: (1) to provide sufficient submergence at the outlet works to prevent the formation of vortices, which could draw floating trash into the outlets and (2) to provide a zone of still water in which to drop out heavy bed load and submerged trash contained in the incoming flow before this material reaches and possibly damages or obstructs the outlet works. The debris pool elevation at Prado Dam was set following hydraulic design procedures specified in applicable guidance, tempered with engineering judgment and consideration of site specific conditions.

5-05 Since 1969, a debris pool elevation of 490 has been maintained at Prado Dam. This elevation, which provides a submergence of 30 feet over the existing outlet works sill at elevation 460, has proven successful in meeting the two objectives stated above. As a result, the same 30-foot submergence was used in the Phase I GDM for the preliminary design of the new outlet works. The invert of the new outlet works was set 10 feet higher at elevation 470 to reduce the length of the conduits and minimize excavation. Accordingly, the debris pool elevation recommended in Phase I GDM was set 10 feet higher at elevation 500. Commensurate with the appropriate level of detail in a feasibility report, no detailed determination of the required debris pool elevation was made in the Phase I GDM.

5-06 Subsequent detailed design studies conducted by the Portland District for the Phase II GDM have revealed that (1) the conduit and gate sizes are controlled by the criteria to release 30,000 ft^3/s at elevation 540, rather than by design criteria for the debris pool and (2) a debris pool elevation of 490 will provide a reasonable factor of safety of 5 feet over the minimum elevation required. This minimum elevation is required for sufficient submergence over the new outlet works to prevent the formation of vortices. This conclusion was drawn from application of design guidance in EM 1110-2-1602, "Hydraulic Design of Outlet Works", paragraph 4-3.c and plate C-35. Thus, the first design objective will be satisfied.

5-07 In terms of the second design objective, a debris pool elevation of 490 will provide a distance of about 8,500 feet from the new outlet works upstream to where the debris pool will daylight against the reservoir bottom along the Santa Ana River. This distance compares favorably with the distance from the existing outlet works to daylighting of about 9,500 feet. Since the existing debris pool elevation has protected the existing outlet works from damage from heavy bed load and trash since 1969, and since the distance to daylighting will be comparable, the same elevation should provide adequate protection for the new outlet works. Formal technical guidance is not available to address this still water zone objective.

5-08 The debris pool elevation of 490 appears to satisfy the two design objectives, at least at the beginning of the life of the project. There is, however, some question regarding the adequacy of this elevation at the end of the project life. Over the 100-year life of the project, a

total of 70,000 acre-feet of sediment is expected to deposit within the reservoir. An estimate of the distribution of this volume of sediment within the reservoir was made following the Empirical Area-Reduction Method in EC 1110-2-241, "Draft Chapters of Sedimentation Manual." The resulting elevation of sediment deposition at the dam's outlet works invert was found to be 488, or 18 feet above the invert of the new outlet works. However, this estimate is contrary to past experience at Prado Dam. Storage at the 490 elevation has reduced from about 13,000 acre-feet in 1941 to about 4,500 acre-feet in 1980. But during the 46-year life of the existing project, no problem with sediment deposition at the outlet has been reported. This lack of deposition at the entrance portal to the outlet works is probably the result of the dense growth of trees in the reservoir inducing deposition well upstream of the dam. For floating debris, a trash boom will be provided. Based on past experience, the debris pool may have to be maintained at elevation 490 for several weeks following periods of heavy inflow to facilitate removal of floating trash. Thus, the debris pool elevation of 490 will satisfy the design objectives and provide adequate protection to the outlet works throughout the life of the project.

5-09 Discussions with Operations Branch personnel indicate that some minor O&M sediment removal from the intake channel has been required in the past and will probably be required for the new project as well. Operations Branch has visually estimated up to 50 percent blockage of the existing trash rack. Blockage occurs during reservoir evacuation periods and only when the wind pushes floating debris toward the trash rack. Small flexible branches (1-inch diameter or less) and barbed wire cause the biggest problem by wrapping around the steel beam elements of the existing trash rack and forming a basket-weave type of blockage. Large trees usually drop out into the reservoir in the forested areas and never reach the trash rack. Removal of the debris can take a six man crew, 1 to 2 weeks, and is usually done after the flood season is over. The new trash rack is designed to have fewer problems with these small flexible branches because: (1) all structural elements will be round concrete beams approximately 24 inches in diameter - small branches are expected to slip off these beams and pass through the gates and (2) the new water control plan will require careful inspection of wind and floating debris conditions and will require the debris pool to be held until it is considered safe to complete reservoir drawdown.

Outlet Works

5-10 A complete discussion of the hydraulic design of the outlet works is provided in appendix C.

Flood Routing

GENERAL

5-11 Flood routings were made using the Los Angeles District computer program "RESFDR." The 70,000 acre-ft of sediment was assumed to have been deposited in the reservoir prior to the floods of interest.

SPILLWAY DESIGN FLOOD ROUTING

5-12 The spillway design flood routing was based on the net capacity curve (fig. V-1), outlet discharge rating curve (shown in appendix B), and spillway discharge rating curve (shown in fig. V-2). The reservoir was assumed filled to the spillway crest (elevation 563.0) at the beginning of the flood, and the outlet was assumed to be regulated according to the operating schedule shown on page 3-2 in appendix B. The spillway design peak inflow of 700,000 ft^3/s will be reduced to a peak outflow of 578,000 ft^3/s. At the maximum water surface elevation of 589.9, the reservoir area will be 17,500 acres, and the net storage will be 659,000 acre-ft. The PMF routing is shown in figure V-4.

Spillway

SPILLWAY DESIGN

5-13 The existing spillway will be modified by raising the crest 20 feet to elevation 563.0 feet and maintaining the length of the crest at 1,000 feet, centered on the existing alignment. Plate 6 shows the profile of the raised invert along the centerline of the proposed spillway from the crest to the connection with the existing portion of the spillway invert, which is to remain. Plate 6 also shows a profile of the proposed top of wall along the spillway and the spillway invert from just upstream from the crest to just downstream from the flip bucket at the terminus of the spillway.

5-14 The design of the spillway invert to accommodate raising the spillway crest 20 feet was accomplished using the Corps computer program H1108, which uses the elliptical upstream quadrant design procedure. An approach depth of 33 feet and design head of 16.5 feet were used. This program provides a lower nappe (i.e., spillway invert) surface similar in shape to that for flow over a sharp-crested weir, resulting in an efficient spillway crest shape.

5-15 A simple vertical curve will be used to connect the new spillway invert to the existing spillway invert. Guidance in paragraph 14 of EM 1110-2-1603 was used to determine the radius of the curve necessary to turn the jet. It was determined that the maximum allowable bucket pressure is 2,000 lb/sq ft. A radius of 20 feet was selected, which will provide a bucket pressure of approximately 970 lb/sq ft.

5-16 The effect of a 20-foot higher spillway crest on the water surface profile in the chute was discussed with hydraulic engineering staff at Waterways Experiment Station (WES). It was concluded that the effect of the higher crest elevation is not readily determined by analytical procedures. Therefore, the water surface profile was based on the results of the hydraulic model testing conducted for the Prado Dam Major Rehabilitation Report for the Dam Safety Assurance Program.

5-17 The design water surface profile for the spillway chute was taken as the maximum water surface at the spillway sidewall recorded for the appropriate conditions during the hydraulic model testing. The minimum freeboard of 2 feet recommended in EM 1110-2-1603 for spillways was increased to five feet to account for the uncertainties regarding waves on the water surface. The resulting top of wall profile is shown on plate 6. For the Feature Design Memorandum, the design of the spillway walls will be verified and refined using the hydraulic model already available at WES.

5-18 An analytical estimate was made of the scour downstream from the flip bucket at the terminus of the spillway. Criteria in HDC 112-8 was used to estimate the throw distance, and an equation for the estimate of the depth of a plunge pool was taken from the U.S. Bureau of Reclamation's Design of Small Dams, 2nd ed., 1973 (p. 410). The analysis indicated that a scour depth of 54 feet will occur. Since the existing toe protection consists of cribbing that extends to a depth of about 92 feet below the invert, the flip bucket will be adequately protected. Confirmation of the performance of the flip bucket will be made during the model study.

SPILLWAY APPROACH CHANNEL

5-19 The model study report for the Prado Dam rehabilitation recommended approach dikes to insure an acceptably uniform flow distribution across the spillway. As a result, the approach dikes shown on plate 4 of the Prado Dam rehabilitation study have been incorporated in the project design. Refinement of the design of the approach dikes will be made from the model study during the Feature Design Memorandum phase. A preliminary determination of energy losses in the approach channel using the HEC-2 computer program indicates losses are minor, between 0.1 to 0.2 feet of head.

SPILLWAY RATING

5-20 The spillway discharge rating curve was determined using Corps program H1107. This program produces a rating curve for an elliptical spillway crest design. The rating curve is displayed in figure V-2.

Freeboard

GENERAL

5-21 Freeboard values for the dam embankment, PMF dikes and the four interior dikes were determined from a combination of wind generated wave height, wave run-up, wind set-up, and wave refraction from various approach fetches in accordance with approved procedures in the following references:

a. Shore Protection Manual, 1977 edition

b. ETL 1110-2-221, NOV 76

c. ETL 1110-2-305, FEB 84

d. Letter from Headquarters to South Pacific Division, 21 NOV 84, 2nd End, Subject: Redbank and Fancher Creeks Project, Freeboard and Riprap Considerations

e. EP 405-1-2, APR 76 (change 6, JAN 79)

EMBANKMENT AND AUXILIARY DIKES

5-22 The top elevation of the dam embankment and the auxiliary dikes was set to contain the Probable Maximum Flood with appropriate freeboard.

5-23 The design criteria for selecting the top of dam elevation requires two spillway design flood routings: (a) starting at the top of the flood control pool (spillway crest), which determines a maximum water surface elevation referred to as freeboard reference level (FRL) "B", and (b) starting at 50 percent of the flood control pool, which determines a maximum water surface elevation referred to as FRL "C". FRL "B" was determined to be 589.9, and FRL "C" was determined to be 589.4. The criteria for the top of dam elevation is the highest of the following three elevations: FRL "B" plus 3.0 feet, or FRL "B" plus wave run-up and wind set-up, or FRL "C" plus 5.0 feet.

5-24 Table V-1 shows the pertinent information for the determination of the top elevation of the embankment and the auxiliary dikes. Applying the design criteria resulted in the governing top elevations (marked by an asterisk).

INTERIOR DIKES

5-25 The top elevation of the interior dikes was set to contain the Reservoir Design Flood pool at spillway crest elevation 563.0 with freeboard allowances determined as discussed below.

5-26 The sites for the four interior dikes are at a wastewater treatment plant owned by the City of Corona, the Alcoa aluminum plant, the Corona National Housing Tract, and the California Institute for Women (CIW). Plates 17, 19, 20, and 22 display the respective dike profiles and show a varied profile according to station along the top of dike. Allowance for earthquake or consolidation effects is discussed in the geotechnical appendix.

Table V-1. Freeboard Determination Data.

	Dam Embankment	Corona Exy Dike	Auxiliary Dike
Wind Direction	N	NNE	NNW
Speed (MPH)	46	44	45
Fetch (Miles)	5.0	5.0	5.7
Significant Wave Height (Feet)	4.3	4.2	4.4
Side Slope (H:V)	2.5:1	2.0:1	2.25:1
Wave Run-Up (Feet)	4.3	4.8	4.7
Wind Set-Up (Feet)	0.2	0.2	0.2
FRL "B" + Run-Up + Set-Up (Feet)	594.4	594.9*	594.8*
FRL "B" + 3.0 Ft	592.9	592.9	592.9
FRL."C" + 5.0 Ft	594.4*	594.4	594.4

*The asterisk denotes the governing top elevation.

5-27 The varying freeboard height shown on plates 16, 18, 20, and 21 was determined from a combination of wave height, wave run-up, wind set-up, and refraction for various approach fetches. The varying height reflects the maximum elevation that water would reach along a particular length of dike, as determined by calculations for wind set-up and wave run-up. The maximum water level is determined either by waves that directly attack a segment of dike from a direction normal to the dike, or by waves refracted from an oblique direction, whichever is greater. Wind velocities ranging from 40 to 58 miles per hour with an average of 50 and duration varying from 14 to 78 minutes with an average of 50 minutes were used for computation. For those segments of a dike where the freeboard was determined to be less than 1 foot, a minimum value of 1 foot was used.

5-28 Freeboard values were based on calculated values of maximum wave height and run-up for all locations except at the ends of dikes. These locations were determined in accordance with ETL 1110-2-299 to be the least hazardous locations for overtopping of the dike when the design flood is exceeded. Consequently, freeboard for the end of each dike was based on calculated values of significant, rather than maximum, wave height and run-up. These end zones will serve as locations to accommodate overtopping from floods exceeding the reservoir design flood.

5-29 A hydraulic analysis of dike overtopping was made to determine how much of each individual dike should be grouted to allow for flow overtopping the dike and prevent dike failure. The grouted area would provide a flow path to fill the interior area to the point where the reservoir area water surface elevations are equalized. It was determined that 200 feet of dike length should be set at elevation 565.0 and 15" of grouted stone placed on the top and interior side slope to allow for overtopping across that portion of the dike.

Slope Protection

5-30 Design of slope protection for embankments and dikes are presented in appendix B.

Interior Flood Control

GENERAL

5-31 An interior flood control analysis was conducted for the auxiliary dike south and east of the spillway and for each of the four interior dikes, following the guidance of EC 1110-2-247, Hydrologic Analysis of Interior Areas. The analysis for the four interior dikes was conducted using three different flood conditions. The conditions were (a) the general SPF interior area flood coincident with the Reservoir Design Flood at Prado, (b) the 100-year local interior area flood coincident with the 100-year general flood at Prado, and (c) the SPF local interior area flood coincident with the SPF general flood at Prado. This procedure provided data on three flood conditions, from which a design condition was selected. The analysis for the auxiliary dike along the railroad tracks was conducted using only the most severe flood combination, which would be the SPF coincident with the SPF.

INTERIOR DIKES

5-32 The interior flood control analysis was based on the assumptions that (a) there will be no excavation of the existing ground at each site, and (b) each site will be drained by a single 36-inch diameter reinforced concrete pipe. Table V-3 shows the results of the interior

flood control analysis for the four respective interior dikes. The level of protection for flood control of the interior of the dikes is the combination of the local SPF coincident with the general SPF, as noted by an asterisk in the table. The table indicates the maximum ponding elevation and the corresponding required area at each dike.

Table V-2. Interior Dike Maximum Ponding Elevation and Required Ponding Area.

Dike Location	Gen'l SPF w/ RDF	Local 100-yr w/Gen'l 100-yr	Local SPF w/ Gen'l SPF
Corona Sewage Treatment Plant:			
Max Elev (ft)	534.6	534.8	537.6*
Req'd Area (acres)	2.2	2.2	2.9*
Req'd Storage Volume (acre-feet)			17.6*
Alcoa Aluminum Plant:			
Max Elev (ft)	547.7	548.2	550.7*
Req'd Area (acres)	7.7	7.9	10.1*
Req'd Storage Volume (acre-feet)			55.6*
Corona National Housing Tract:			
Max Elev (ft)	552.3	553.6	555.6*
Req'd Area (acres)	1.4	1.8	3.0*
Req'd Volume (acre-feet)			11.1*
California Institute for Women:			
Max Elev (ft)	554.0	555.3	556.7*
Req'd Area (acres)	6.1	10.9	16.3*
Req'd Storage Volume (acre-feet)			41.3*

*The asterisk denotes the governing flood condition.

AUXILIARY DIKE

5-33 The auxiliary dike and floodwall that will be aligned parallel to the AT&SF railroad tracks will intersect five streams which empty into Prado Reservoir. An interior flood control study was performed to determine how this dike will affect flows from these streams. The close proximity of the railroad embankment to the dike and floodwall makes it necessary to prohibit impoundment of water for any significant length of time. Accordingly, the water will not pond for longer than the duration of the local storm (6 hours) in the area of the railroad embankment. It was assumed that flows would pass the railroad embankment through the railroad culverts and/or over the railroad tracks without diversion. Further refinement of the design of the railroad dike drains will be conducted during the preparation of contract plans when more detailed topographic mapping of the affected area will be available.

5-34 Three subareas, designated A1, A4, and A5 in figure V-3 will drain independently, without local runoff spilling across watershed boundaries into an adjacent subarea. That the remaining two subareas A2 and A3 will drain together through the railroad dike to avoid flooding new development immediately downstream from subarea A3. The drain for subarea A2 will be the closest location for runoff diverted from subarea A3 to enter the reservoir.

5-35 To connect the outlets of subarea A3 with subarea A2, a diversion drain will be constructed parallel with the floodwall for approximately 1,100 feet (pl. 12). A storm drain has been recently constructed for a new development within subarea A3. This drain was assumed to collect and convey runoff from subarea A3 up to its design capacity of 176 ft^3/s. The diversion drain was sized to convey a discharge of 286 ft^3/s which is the difference between the capacity of the new drain and the local SPF peak discharge of 462 ft^3/s. The diversion drain was designed to flow full with headwater and tailwater elevations below the divides of the adjacent subareas as discussed in paragraph 5-32 above. A 72-inch-diameter reinforced concrete pipe (RCP) will be required.

5-36 Four culverts were designed to convey flows from the respective subareas through the auxiliary dike into the reservoir. Trial culvert sizes were selected and rating curves for both inlet control and outlet control were prepared for each size. The culvert size required to satisfy the design criteria discussed in paragraphs 5-31 and 5-32 above was determined using the HEC interior drainage program INTDRA. Inflow hydrographs were routed through the depression upstream from the embankment at each respective subarea for each trial culvert size against the stage hydrograph for the coincident flood condition at Prado. Table V-3 displays the drainage area, maximum inflow and outflow, and pipe size required to carry the maximum outflow for each subarea.

5-37 The minimum freeboard from the upstream water surface at the culvert inlet to the top of the auxiliary dike is at least 23 feet for all four culverts. Plate 11 shows culvert locations, and plate 12 shows the respective culvert data.

Table V-3. Culvert Sizes at Auxiliary Dike.

Subarea	Drainage Area (acres)	Maximum Inflow (ft^3/s)	Maximum Outflow (ft^3/s)	Pipe Size (in)
A1	233	866	462	84
A2	117	728	399	72
A3	120	Excess flows for this Subarea are combined with Subarea A2		
A4	21	94	80	36
A5	15	69	51	36

VI. GEOLOGY, SOILS, AND MATERIALS

Extensive geological, seismological, and materials investigations were conducted at Prado Dam in order to analyze and evaluate the existing earthfill structure for the proposed modification of the dam as presented in this report. Results of field investigations and laboratory tests, and recommended design and construction considerations are presented in Appendix B, entitled Geotechnical Appendix.

VII. STRUCTURAL DESIGN

General

7-01 Structural design for various reinforced concrete features of this project includes: retaining walls on the top of the existing spillway embankments, wing walls at the entrance of the outlet works, a training wall at the spillway approach, floodwalls at the auxiliary dike and at Corona National Housing Tract, conduits of various diameters under the proposed dikes with inlet and outlet structures, and modification of the existing ogee section for the spillway. Structural design for the outlet tower, tunnel, stilling basin, and access bridge are presented in Appendix C, entitled Outlet Works.

References

7-02 All structures would be designed in accordance with applicable provisions of the following Engineering Manuals (EM's), Engineering Technical Letters (ETL's), and Engineering Regulations (ER's).

Reference	Title
EM 1110-1-2101	Working Stresses for Structural Design
EM 1110-2-2000	Standard Practice for Concrete
EM 1110-2-2103	Details of Reinforcement-Hydraulic Structures
EM 1110-2-2502 (Draft)	Retaining Walls, Floodwalls
EM 1110-2-2902	Conduits, Culverts and Pipes
ER 1110-2-1806	Earthquake Design and Analysis for Corps of Engineers Projects
ETL 1110-12256	Sliding Stability
ETL 1110-2-256	Strength Design Criteria for Hydraulic Structures

Unit Design Stresses

7-03 Unit Design Stresses used in the design of the proposed structures are given in the following table:

Table VII-1. Unit Design Stresses, Weight and Properties.

CONCRETE

Ultimate Compressive Strength

Cast-in-place structures other than culverts (box and railroad bridge) f'c = 3,000 psi
Box culverts (including railroad bridge) f'c = 4,000 psi
Modulus of elasticity Ec = 57,000 $(f'c)^{1/2}$

REINFORCING STEEL

Grade 40: Yield Strength = 40,000 psi

Grade 60: Yield Strength = 48,000 psi

Modulus of Elasticity = 29,000,000 psi

WEIGHT AND PROPERTIES

Concrete Weight	150 pcf
Water Weight	62.5 pcf

SOIL PROPERTIES

	Backfill	Foundation
Moist Weight (pcf)	130	124
Saturated Weight (pcf)	137	131
Internal Friction Angle (degree)	38	35
Equivalent Fluid Pressure Coefficient: Active (K_A)	0.24	---
At Rest (K_p)	4.2	---
Allowable Bearing Pressure (psf)	---	4,000

Seismic Force

7-04 All retaining and flood walls and the ogee section would be designed in accordance with ER 1110-2-1806, titled "Earthquake Design and Analysis for Corps of Engineers Projects." The ground acceleration of 0.2g would be used for the evaluation of seismic force.

Retaining Walls

7-05 Retaining walls would be located near the ogee section near the chute of the existing spillway, and at the entrance of the proposed outlet works. These walls would be designed either as an inverted T-wall or a counterfort wall, depending on their heights.

WALLS AT THE SPILLWAY

7-06 The proposed modifications to the dam includes raising the existing dam embankment by 28.4 feet. A retaining wall would be required to retain embankment fills between station 10+40 and station 12+10 of the spillway on both banks. The heights of retaining wall on the right bank would vary from 32 to 9 feet and the length would be approximately 170 feet. The wall heights on the left bank would range from 22 to 4 feet and the length would be about 200 feet. The spillway wall between station 12+10 and station 20+20 would be extended by paving the existing berm and side slope with 8 and 6-inch thick concrete respectively (pl. 7). Another vertical wall would be needed for retaining the designed flow on each side of the spillway between stations 20+20 and 21+20. The height of wall varies from 12.6 feet to 0 feet and the length would be approximately 130 feet (pl 7).

LOADING CONDITIONS FOR RETAINING WALLS

7-07 The retaining walls at the spillway would be designed in accordance with EM 1110-2-2502 for four loading conditions. (1) Case I loading: earth pressure on the back of the wall would be determined in accordance with criteria contained in Civil Works Engineer Letter 64-7, 22 April 1964; Subject: "Construction Stresses in Retaining Walls". The lateral earth pressure would be computed for a condition of drained backfill. The triangle distribution of the horizontal earth pressure due to backfill material would be assumed in the design of the wall stem and footing. A vertical friction force with a coefficient equal to the tangent of 3/4 of internal friction angle (in degrees) of the backfill material would be assumed to act on the back of the walls. Straight line distribution of soil pressure would be assumed in the design of the wall footings. (2) Case II loading: In addition to the Case I loading, a maximum loading of 200 psf due to construction equipment would be applied at the top of the wall; the loading then would be decreased by the unit lateral earth pressure Kw at each foot of depth. (3) Case III loading: Seismic force would be applied to the wall. The static lateral forces would be determined from the single wedge equation given in the manual. In addition to the static forces, the lateral forces produced by horizontal and vertical seismic accelerations acting on these wedges would be applied to the structural wedge for calculation of sliding and overturning stabilities. (4) Case IV loading: Wind force

would be applied to the channel face of wall with no backfill behind the wall. This condition governs the design of channel face reinforcement and occurs only under construction.

7-08 The walls would be designed so that the stability requirements are satisfied, i.e., the resultant of vertical and horizontal forces would fall within the middle third of the footing, soil pressure under the wall footing would be less than allowable bearing pressure, and the safety factor against sliding would be greater than 1.5. Vertical reinforcing steel in the channel face of the wall would consist of either reinforcong bars 1/2-inch in diameter and spaced on 18-inch centers or reinforcing bars comprising 10 percent of the vertical steel in the back of the wall, whichever gives the greater area of steel.

Training Wall

7-9 The training wall would be located on the right bank of the spillway and extending to join the proposed retaining wall at station 11+00. The 300-foot long wall would have a wall height varying from 30 to 40 feet, and the top of the wall at elevation 589.4 feet. The wall height would vary according to the existing ground elevation. A stepped footing would be used for the upstream half of the wall for a length of approximately 150 feet.

7-10 The training wall would be designed for two loading conditions. Condition I loading the reservoir would assume the reservoir to be empty with seismic or wind forces on the wall. Minimum seismic acceleration of 0.2 G or minimum wind force of 30 psf would be considered in the design. Condition II loading would assume the reservoir to be full and a water difference of 3 feet would be considered.

Floodwalls

7-11 Floodwalls would be provided at three locations. One floodwall, located at the east end of the auxiliary dike, from station 20+00 to station 4+86, would vary in height from 17.0 feet to 5.0 feet and having a top of wall at elevation 594.4. Due to the existing terrain, wall heights would vary and a step footing would be provided between station 12+00 and station 4+86.

7-12 The second floodwall would be constructed on the north side of the Corona National Housing Tract, between station 29+20 and station 40+00. The top of the masonry wall would be at elevation 566.0 and the height of the wall would be approximately 8 feet for the entire length.

7-13 The third floodwall would be located near the west abutment of the existing main embankment. The length of the wall would be about 150 feet. The top of the wall would be at elevation 594.4 and a step footing would be provided according to the existing ground surface elevation.

7-14 Floodwalls would be designed as inverted T-type walls. Horizontal footings instead of sloping footings would be used for simplicity of onstruction. The applied forces would be hydrostatic forces above and

below ground elevation, the weight of concrete and earth, and other surcharges above the base of the wall. Uplift pressure on the base would be considered in the stability computation. The pressure would be maximum at landside, and minimum at waterside of the base. Two different water elevations would be considered in the design. In one case, the 3-foot freeboard would be ignored, and the resultant force would fall within middle half of base. In the second case, the freeboard would be considered and the resultant must fall within middle third of the base.

7-15 To minimize the possibility of boils and blowouts in the foundation material above the toe of footing, limitatations must be set on the minimum distance through which any given net head will be required to travel. Minimum permissible creep ratio (creep path distance divided by net head) would be 3.0. A cutoff wall with toe drain would be provided as required.

Culverts

7-16 Reinforced concrete pipes would be provided through the auxiliary and ring dikes in the reservoir area. The culvert data such as stations, pipe inside diameters, lengths, etc., are shown on plates 12, 17, 19, 20, and 21. The design criteria would be as follows:

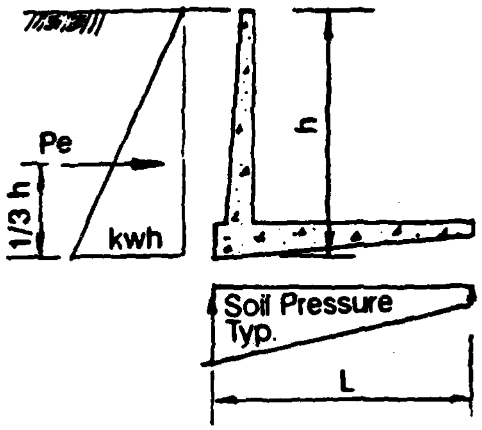
a. The vertical pressure would be equal to 1.5 times the height of the fill multiplied by the unit weight of the embankment material, and horizontal pressure would equal to 0.5 times the height of fill multiplied by the unit weight of the embankment material.

b. Both the vertical and horizontal loads would equal the height of fill multiplied by the unit weight of the embankment material. Portions of culverts would be encased where the loading exceeds the R.C.P. strength. A reinforced concrete inlet and outlet structure would be provided for each culvert.

Modification of Ogee Section

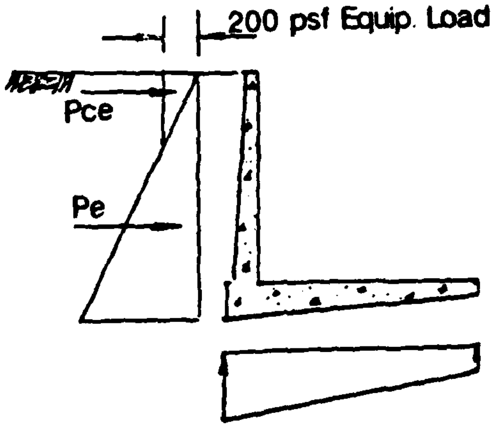
7-17 The existing ogee is a gravity section with a maximum height of 13 feet above the invert elevation and a crest length of 1,000 feet. The proposed modification would raise the crest elevation by 20 feet to elevation 563.00. In order to form a monolithic unit, the existing invert concrete and subdrainage system between station 11+20 and station 11+80 would be removed and reconstructed. Waterstops would be provided along longitudinal construction joints and spaced approximately 30 feet on centers, between station 10+98 and station 11+45.82.

7-18 The modified ogee section would be designed in accordance with EM 1110-2-2400. As there is no subdrain system below the ogee section, uplift loading would be assumed to be over 100 percent of the base area. The uplift force at upstream end would be equal to full hydrostatic pressure and be uniformly reduced to the tailwater surface at the downstream end.



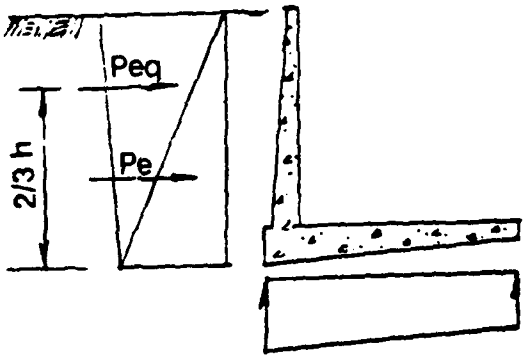
CASE I

Horizontal Earth Pressure



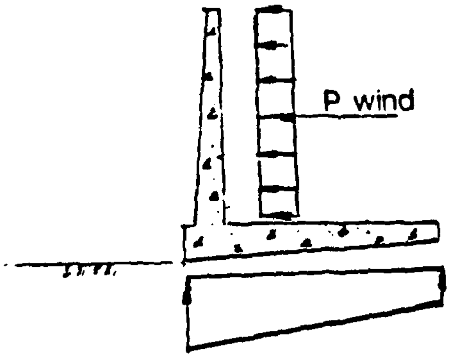
CASE II

Case I with Construction Equipment Load



CASE III

Case I with Seismic Force

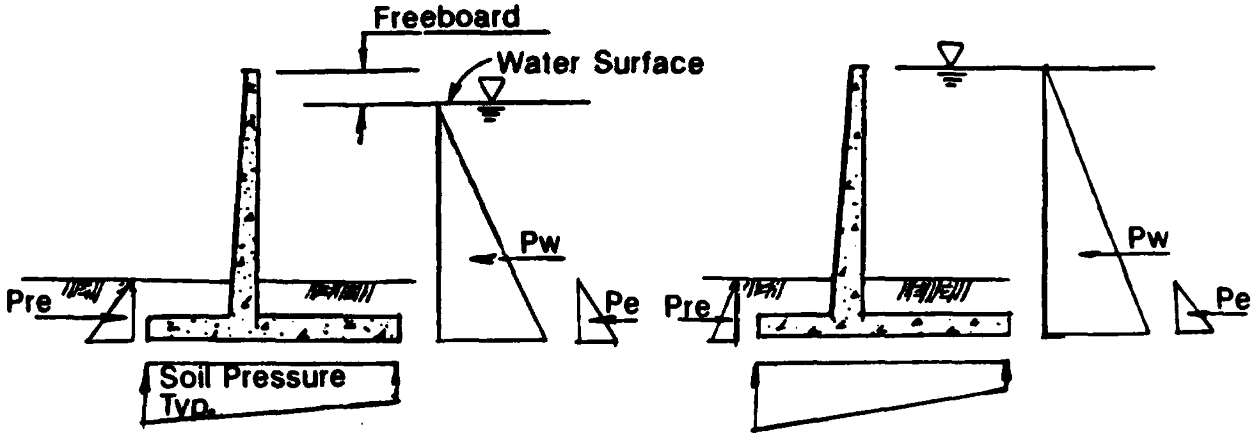


CASE IV

Wind Force with No Backfill under construction

RETAINING WALL LOADING CONDITIONS

Note: Loads are unfactored

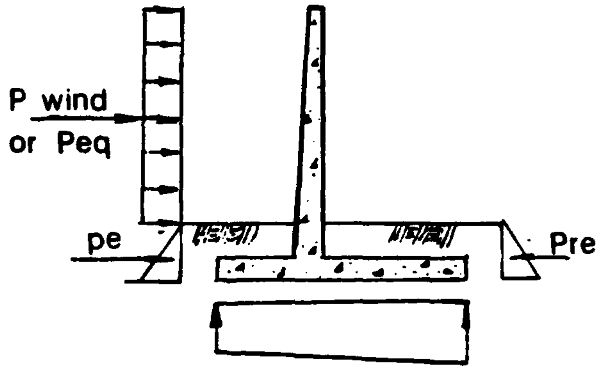


CASE I

Design Water Level

CASE II

Extreme Flood

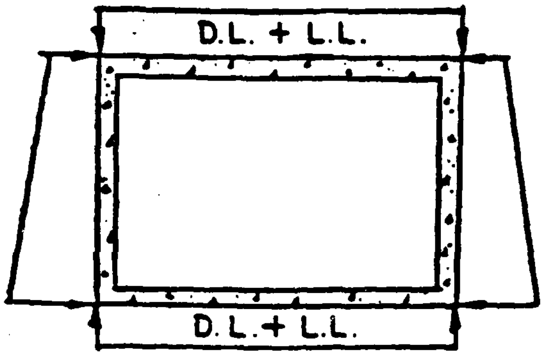


CASE III

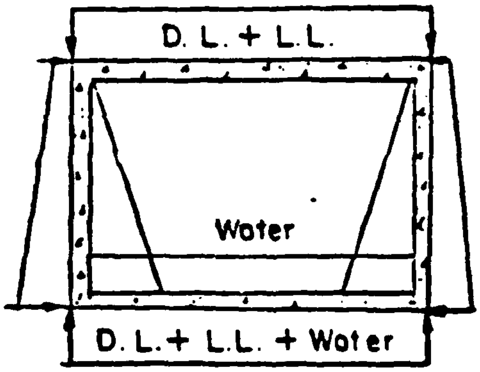
Wind or Seismic Force

FLOODWALL LOADING CONDITIONS

Note: Loads are unfactored



CASE I NORMAL LOAD
DESIGN OF CORNER



CASE II NORMAL LOAD WITH WATER
DESIGN OF MIDSPAN

BOX CULVERT LOADING CONDITIONS

Note: Loads are unfactored.

VIII. MODIFICATION OF HIGHWAYS AND STREETS AND RELOCATION OF UTILITIES

General

8-01 Construction of the recommended features for enlargement of the existing Prado Dam would result in modification of the Corona Expressway, and five streets including Clearwater Drive, Smith Avenue, Butterfield Drive, Rincon Street, and Auburndale Street. Existing utilities such as overhead power and telephone lines in the vicinity of the dam embankment and along existing streets, and a 30-inch gas line at the downstream slope of the dam would require relocation.

The Corona Expressway

8-02 The existing Corona Expressway is an important transportation artery in the southwestern part of San Bernardino County and connects the Riverside Freeway (Highway 91) from the South and the Pomona Freeway (Highway 60) plus the San Bernardino Freeway (Interstate Highway 10) to the north. The 4-lane (except certain reaches) Corona Expressway is heavily used, and the traffic volume will continue to increase in the future. CALTRANS plans to increase the capacity of the expressway by providing additional traffic lanes and construction is scheduled to begin in the 1990's. Raising the existing expressway to elevation 594.4 at the intersection with the axis of dam embankment would affect the road grade extending from this point to the interchange with Riverside Freeway, and would significantly increase the construction cost for future expansion of Corona Expressway. The recommended modification would have the high point located approximately 2,000 feet north of the dam axis, thus eliminating any modification to the existing road grade south of dam. This design would also reduce the future construction cost for the expansion of the expressway. The dike along the east side of the freeway would be compatible with the CALTRANS expansion plan.

8-03 Prior to construction of the expressway, a paved detour with the necessary traffic control signs, stripes and signals would be provided on top of the lower portion of the proposed dike along the highway. Flagmen would be provided at the site whenever necessary. Asphaltic

pavement on the existing highway as well as on the detour would be removed prior to placement of additional fill. Pavement design and provisions for traffic control devices such as striping, guard rails, signs, and signals would conform to CALTRANS' standards.

Streets

8-04 Streets in the City of Corona would be modified to accommodate the crossing of the proposed ring dikes. In general, modification would be limited to raising a segment of the street to the top of the dike with a mild sloping ramp on each side. The height and length of each ramp would depend on the existing terrain condition and the height of dike. Construction time at each crossing would depend on its size and complexity, but a detour would be provided during the construction period. Design criteria for the streets to be modified would be consistent with existing conditions with no betterment to be included.

SERFAS CLUB DRIVE

8.05 This street, formerly known as Pomona-Rincon Road, was renamed recently in connection with a new commerical-industrial development located just north of the proposed flood wall for the auxiliary dike. The proposed modification would affect approximately 230 feet of the street with its existing surface raised to a crest at elevation 590 and ramps at 7.0 and 5.0 percent slope on the north and south side, respectively.

CLEARWATER DRIVE

8-06 The existing drive at the Corona Sewage Treatment Plant would be raised from the existing top of road at elevation 540 to the top of dike at elevation 566. The ramp on the northeastern side of the dike would be approximately 450 feet in length with a slope of 7.5 percent, and the desending ramp on the southwestern side would be about 300 feet in length with grade of 4.7 percent.

BUTTERFIELD DRIVE

8-07 This is the main road to the City of Corona's Municipal Airport. The first 850 feet of the street would be affected by the crossing of the dike with its top at elevation 569.8. The ramp on the west side of the dike would be 420 feet in length with a slope of 5 percent, while the ramp on the east side would be 330 feet in length with an identical slope.

RINCON ROAD

8-08 Modification of Rincon Road would occur at two different locations; one located approximately 460 feet west of Smith Avenue and the other situated about 2,300 feet east of Smith Avenue. The first crossing would involve raising the existing road surface from elevation 541 to elevation 569.8. The ramp on the west side of the dike

would be 600-feet in length with a grade of 6 percent, whereas the eastern ramp would be 450-foot long having a slope of 6.5 percent. The second crossing would be rather short with only 240 feet of Rincon Road to be modified. The ramp on both sides of the dike would be similar with identical slopes of 6 percent, whereas the length of ramp being 130 feet on the west side of the dike and 110 feet on the east.

AUBURNDALE STREET

8-9 The southern end of Auburndale Street would be modified by raising the top of road from elevation 550 to 566. The ramp from Rincon Street to the top of dike as well as the descending ramp on the north side of dike would have a slope of 6.5 percent. The total length of the street to be affected by the proposed modification would be approximately 500 feet.

Utilities

POWER TRANSMISSION LINES

8-10 A major item on the list of utility relocation would be the existing 500 KV, a 220 KV, and a 66 KV transmission lines (owned by Southern California Edison Company) located on the various parts of the reservoir. The low wires would be raised, in accordance with ER 1110-2-4401, to provide a minimum distance above the water surface of the reservoir design flood.

GAS LINES

8-11 Another major item of relocations would be the 30-inch diameter gas line located in the south side of the dam embankment and in the area of the proposed outlet works. The existing gas line owned by the Southern California Gas Company would be protected in place at the location near the right abutment of the dam where approximately 20 feet of fill would be placed over about 400 feet of the existing line. In the area of proposed outlet works where approximately 500 feet of the existing gas line would be relocated due to exposure by excavation for the approach channel.

8-12 Other known utilities which would be affected by the construction of interior dikes are listed in table VIII-1.

Table VIII-1. List of Existing Utilities to be Relocated, Modified, or Protected in Place.

Location	Existing Utility	Owner	Remarks
Dam Embankment	30" Gas	So. Cal. Gas	500' to be relocated and 800' to be protected in place
	3" Gas	So. Cal. Gas	350' to be relocated
	Powerline	So. Cal. Ed.	3,000' to be relocated
	Telephone Line	Pacific Tel.	3,000' to be relocated
Reservoir Area	1-500 KV trans. line	So. Cal. Ed.	7,000' to be raised
	1-220 KV trans. line	So. Cal. Ed.	7,000' to be raised
	1-66 KV trans. lines	So. Cal. Ed.	Various lengths to be raised
Dike at Alcoa Aluminum Plant	18" Sewer	City of Corona	Two manholes to be raised and 470' to be protected in place
	10" Water	City of Corona	470' to be protected in place
	8" Sewer	City of Corona	450' to be protected in place
	Powerline	So. Cal. Ed.	Two poles to be relocated
	Telephone Line	Pac. Tel.	One pole to be relocated
	6" Sewer force main	City of Corona	650' to be protected in place
	12" Water	City of Corona	650' to be protected in place
	10" Sewer	City of Corona	Two manholes to be raised and 650' to be protected in place
	Sewer Pump Station	City of Corona	To be flood proofed

IX. DESIGN OF HIGHWAY, DIKE RAMPS AND ACCESS ROADS

General

9-01 The recommended enlargement of Prado Dam includes modification of the Corona Expressway (Highway 71), construction of ramps at the intersection of the proposed ring dikes with existing streets, and construction of service roads and ramps at the dam. This chapter presents the geometric design criteria for the highway and ramps, and presents proposed criteria and pavement designs for the service roads and ramps.

Geometric Design

9-02 The geometric design for existing Highway 71, including its detour, would be in compliance with the policy and practice of the Transportation Department of the State of California (CALTRANS). The design for dike ramps at the road crossings would be in accordance with the report entitled "A Policy of Geometric Design of Rural Highways" by the American Association of State Highway and Transportation Officials (AASHTO). The design would also conform to the standards of the Federal Highway Administration for secondary roads of low usage.

Pavement Designs

HIGHWAY 71

9-03 The modifications to Highway 71 and the detour will be designed by CALTRANS, and will be based on their criteria.

PUBLIC ROADWAYS

9-04 Several public thoroughfares in the City of Corona will require alteration to accommodate the proposed auxiliary dike and dikes around the Alcoa Aluminum plant and the municipal sewage treatment plant. Design of these pavement sections will be based on the existing roadway cross sections as shown on plans supplied by the City of Corona.

a. Serfas Club Drive, serving the newly developed commercial-industrial center will have a pavement section consisting of 0.95 feet of aggregate base course and 0.30 feet of asphaltic concrete pavement.

b. Clearwater Avenue, which serves as the main access to the Corona sewage treatment plant, will have a pavement cross section consisting of 0.95 feet of aggregate base course and 0.25 feet of asphaltic concrete pavement.

c. Rincon Street passes over the aluminum plant dike at two locations, one just west of its intersection with Smith Avenue and again east of its intersection with Auburndale Street. At both crossings the roadway cross section will consist of 0.95 feet of class B aggregate base course overlain with 0.30 feet of asphaltic concrete pavement.

d. Butterfield Drive intersects the aluminum plant dike just west of its intersection with Smith Avenue. The pavement section will consist of 0.95 feet of class B aggregate base course overlain with 0.25 feet of asphaltic concrete pavement.

e. Auburndale Street crosses over the aluminum plant dike just north of its intersection with Rincon Street. The pavement section will consist of 0.95 feet of class B aggregate base course overlain with 0.25 feet of asphaltic concrete pavement.

EMBANKMENT AND ACCESS ROADS

9-05 The subgrade along the road alignments would be compacted native material. Based on tests of similar materials a conservative California Bearing Ratio (CBR) value of 15 will be adopted for the subgrade compacted to 95 percent of its maximum density (determined by ASTM D 1557 test method). Along the embankments, a CBR value of 10 will be used for the dike material compacted to 95 percent of its maximum density (determined by ASTM D 1557).

9-06 All access roads, including the ramp from Highway 71, and roads on top of embankments will be designed as single lane, Class F, Category 1 roads. These design values are based on the expected traffic makeup and volume. These roads will have a cross section consisting of 2 inches of bituminous pavement placed on 5 inches of compacted subgrade.

X. SITE RESTORATION

Dikes

10-01 Construction of the dikes would consist of stripping the top 12 inches of existing surface material from the entire area under the embankment, importing embankment material from borrow areas, and importing riprap from a commercial source. Approximately, 40 percent of the stripped material would be stockpiled at the site and would be used as top soil over the downstream (land side) slope of the dike. The remaining surplus material would be hauled and used for restoration of the borrow areas. The embankment borrow and riprap would be placed immediately and directly on to the structure during construction, therefore, the need for a stockpile would be mainly limited to the stripped material. Site restoration at the dikes would be required for the stockpiling area. Restoration work would include, but not be limited to clearing the stockpiling area of any trash or unused material, and returning the area to its original elevation and appearance.

Borrow Pits

10-02 It is difficult to predict the final location, size and configuration of the borrow areas. The location, depth, and size of the borrow pits would depend on availability of suitable embankment material which could be excavated conveniently at low cost. Approximately 6 inches of the top material would be stripped, and stockpiled for use as top soil over the disturbed borrow site upon completion of borrow operation. The side slopes of the pits would be regraded to a slope of 1 vertical on 5 horizontal; and the bottom of the pits would be graded to drain to existing water courses to prevent ponding of water at the end of construction.

Haul Roads and Access Roads

10-03 Haul roads and vehicular access roads would be needed during construction of various features of the flood control structures. Construction roads would be constructed on higher ground and would be unpaved. Temporary culverts and dip crossings would be required. A graveled surface may be used to allow continuous road service under all weather conditions. Site restoration would include removal of any drainage structures, and any pavements or treated soil which would be detrimental to the growth of vegetation. Untreated haul roads would be scarified to allow the disturbed area to return to its original condition.

Cleanup After Construction

10-04 The contractor's yard and storage area would be the center of activities for cleanup after construction. Upon completion of construction, the contractor would be required to restore the site to its original condition to the extent possible. Site cleanup would include, but not be limited to, the removal of fences, concrete foundations, asphalt pavement, abandoned equipment, trash, etc. Oil spills in an area near a water course would also be removed and disposed to an appropriate disposal area.

XI. ESTHETIC TREATMENT

General

11-01 Construction of the dike embankments and the raising of the existing top of the dam would alter the visual quality and character of the site. The dikes include the auxiliary dike along the Santa Fe Railway from the existing spillway to Serfas Club Drive, and the ring dikes for the Corona Sewage Treatment Plant, Alcoa Aluminum Plant, Corona National Housing Tract, and the California Institution for Women. The auxiliary dike and the main dam would be readily viewed by motorists from the Corona Expressway (State Highway 71) and the Riverside Freeway (State Highway 91). The ring dikes would be viewed by community residents in the immediate project area.

11-02 Borrow excavation for construction of the embankments would leave large scars in these areas and the barren embankments themselves would have a significant visual impact on the surrounding landscape. The esthetic treatment program would be designed to minimize the immediate visual scars and the long-range effects of this alteration to each individual site. The program would also enhance the visual quality of the project features and restore the borrow area as closely as possible to the surrounding topography.

11-03 During the construction phase, the esthetic treatment program would emphasize controlling any unnecessary damage to the environment by limiting disturbances by the contractor to previously designated areas. The contractor would be required to conduct on-site supervision of his men and equipment and emphasize the importance of environmental preservation.

11-04 In reshaping the borrow area, natural topography and existing features would be considered, such as existing plant materials, rock outcroppings and any other features of interest. Upon completion of construction, haul roads would be made impassable to vehicular traffic by scarifying their surfaces and being left in a condition that would facilitate revegetation.

11-05 The dikes at the Corona Housing Tract and Corona Sewage Treatment Plant will be seeded with forbs and grasses on their landward side embankments. Trees would be planted within the right-of-way on the landward side, a minimum of 10 feet from the toe of the dike. The side slopes and borrow area would be graded to no less than a 5 horizontal to 1 vertical. The side slopes and borrow area would also be seeded and a maintenance period would be established to ensure adequate germination. Once esthetic treatment is established, the flood control features would blend in with their surroundings. Due to safety inspections required for the main dam and auxiliary dike, seeding would not be provided at these flood control features. However, since the main dam and auxiliary dike are in highly visible areas, consideration would be given to rock treatment by both rock staining and use of many rock types of varied size, color and texture on the downstream embankment to provide a mural type effect.

Plant List

11.06 A list of potential plants for use on the downstream embankments of the ring dikes are listed below.

Scientific Name	Common Name
Festuca megalura	Zorro Fescue
Mimulus longiflorus	Monkey Flower
Lupinus bicolor	Lupine

Potential trees and or large shrubs for planting within the rights-of-way at ring dikes are listed below:

Rhus laurina	Laurel Sumac
Quercus agrifolia	Coast Live Oak
Fraximus dipetala	Flowering Ash
Platanus vacemosa	Sycamore
Heteromeles arbutifolia	Toyan
Populus trichocarpa	Black Cottonwood
Populus fremontii	Fremonts Cottonwood
Salix gooddingii	Black Willow
S. hindsiana	Sandbar Willow
S. laevigata	Red Willow
S. lasiolepis	Arroyo Willow
Sambucas mexicana	Elderberry

For the borrow areas, the following plant species would be utilized for borrow area No. 1.

Rhus trilobata	Squaw Bush
Adenostoma fasciculatum	Chamise
Eriogonum fasciculatum	Common Buckwheat
Lotus scoparius	Deerweed
Artemesia californica	California Sagebrush
Encelia californica	Desert Encelia
Salvia apiana	White Sage
Salvia mellifera	Black Sage
Festuca megalura	Zorro Fescue
Lupinus bicolor	Lupine

For borrow area No. 2, the following species will be used for replanting.

Hordeum vulgare	Barley
Trifolium hiratam	Rose Clover (var. Hykon)
Festuca megalura	Zorro Fescue

Along the bottom edge of the slopes of the borrow areas, Baccharis glutinosa (Mule-Fat) would be planted in 20 to 30-foot band.

Cost Estimate

11-07 Detailed cost estimate for the proposed esthetic treatment on various features of the project is shown in table XI-1.

Table XI-1. Estimated Cost for Esthetic Treatment.

Description	Quantity	Unit	Unit Price	Cost
Rock Treatment				
Main Dam (downstream)				
Rock Staining	37,000	S.F.	0.13	9,000
Add Imported Rock/Gravel	1,100	C.Y.	30.00	33,000
Auxiliary Dike (downstream)				
Rock Staining	200,000	S.F.	0.13	38,000
Add Imported Rock/Gravel	3,480	C.Y.	30.00	104,000
15-Gal Trees (single stake)	118	Ea.	80.00	10,000
Drip-Irrigation System	1	Job	L.S.	3,000
Seeding with Soil Amendments (lndwrd side)				
Dike at Sewage Treatment Plant	308,000	S.F.	0.17	52,000
Dike at Housing Tract	112,000	S.F.	0.17	19,000
Seeding Borrow Areas	5,200,000	S.F.	0.12	624,000
Irrigation, Main Line	5,750	L.F.	3.00	17,000
Irrigation, Lateral Lines	11,500	L.F.	1.90	22,000
Spray Heads, Lawn Rotary	230	Ea.	90.00	21,000
Miscellaneous Irrigation Components	1	Job	L.S.	10,000
90-Day Maintenance	1	Job	L.S.	16,000
TOTAL				$978,000

XII. RESOURCE USE PLAN

Project Background

12-01 Construction of Prado Dam was authorized by the Flood Control Act of 1936 (Public Law 74-738), as amended, as part of a general plan for the construction of flood control facilities in the Santa Ana River Basin, California. Construction of the dam was completed in May 1941. The Flood Control Act of 1944 (Public Law 78-534), as amended, authorized the U.S. Army Corps of Engineers (COE) to both construct, maintain, and operate public park and recreational facilities at water resource development projects and to authorize local interests to do the same. Existing recreation facilities within the Prado Basin have been developed under the auspices of the COE Code 710 Program - recreational development at completed COE projects. Recreation facilities developed under the COE Code 710 Program require the local sponsoring agency to assume all responsibilities for operation and maintenance.

12-02 The initial study of recreation potintial for Prado Dam was authorized by the Federal Water Project Act of 1965, and as required by the Federal Water Project Act of 1965, Public Law 89-72, full consideration must be given to the opportunities for public outdoor recreation afforded by the water resource development project. The Water Resource Development Act of 1976, Section 109, authorized the Phase I advanced engineering and design for the Santa Ana River Project. The Phase I General Design Memorandum included recreation as a project purpose and was submitted in September 1980, and approved in January 1982. The recreation plan as noted in the Phase I GDM included recreation lakes. Upon review of the Phase I GDM, the Office of Policy directed the COE to reformulate the recreation plan based on their determination that the COE had no authority to participate in the development of recreation or multi-purpose lakes. There will be an economically viable recreation plan identified in a subsequent supplement to the Phase II GDM. Authorization for construction of Prado Dam was contained in the Water Resource Development Act of 1986.

12-03 During the Phase II recreation study no local sponsor expressed firm interest or commitment to participate in site-specific cost shared recreation facilities. As a result of this lack of commitment, the COE prepared a Resource Use Plan based on land use analysis, and environmental sensitivity and suitability which would provide a guide for all future development within the Prado Basin (appendix D).

12-04 The Prado Basin Resource Use Plan is presented in appendix D of this volume.

12-05 The Prado Dam flood control basin presently serves as the major flood control facility along the Santa Ana River corridor. Since the completion of Prado Reservoir, urbanization and related development pressures have increased adjacent to and downstream from the reservoir. A flood hazard exists within the rapidly developing urban areas of Orange, Riverside, and San Bernardino Counties. Expansion of Prado Reservoir has been proposed to alleviate this potential threat.

12-06 The Prado Basin offers a large area of open space and the potential for recreation opportunities in the heavily urbanized Los Angeles area. The COE has a cooperative program with both public and private sectors for development of facilities within the basin. The basin also has a long standing tradition of agricultural use, which consists of dairies, ranches and farms. Few commercial or industrial activities are located within the basin.

12-07 The primary purpose of the reservoir is flood control; all lessees, sublessees, and property owners understand and have agreed in writing that their operation, facility or land is subject to periodic flooding. Current land uses include a variety of recreation uses, agriculture (on an interim basis), oil and gas leases, and public works projects, such as sewage treatment and percolation ponds.

Purpose of the Resource Use Plan

12-08 In conjunction with the proposed expansion of Prado Reservoir, the COE prepared this report to serve as a comprehensive guide for land use planning within the Prado Basin. The Resource Use Plan is intended as a general guide to assist in determining the capability of Prado Basin to accomodate specific development proposals.

12-09 The Plan provides guidelines for the orderly and coordinated management and development of all land and water resources within the Prado Basin. The Resource Use Plan is not site specific. Rather, it recommends potential compatible uses with the resources of Prado Basin, characterizes the basin's present land use, and provides guidelines on development due to flooding and environmental considerations.

12-10 In preparing this plan four goals were identified:

a. Utilize the report to serve as a guide for land use planning useful to the Corps of Engineers staff, county and local planning officials, and private developers.

b. Provide a Resource Use Plan which reflects Federal regulations and policy, which minimizes flood damage to property and protects specific environmental resources.

c. Provides guidelines for evaluating proposed uses and developments, including resource use objectives, resource element data, flood inundation level constraints, and existing site feature data.

d. Preserve the flood control integrity of the Prado Basin, and consider all appropriate development proposals.

Description of Resource Use Plan

12-11 The Resource Use Plan map for Prado Basin reflects land use restrictions based on two major determinants, resource sensitivities, including existing land uses, and flood inundation levels. Resource sensitivities reflect the sensitivities of the biological and cultural resources within the basin. Both resources, as stated previously, are protected by Federal regulations and COE policy. Another resource element, existing land uses, is directly incorporated into the analysis as part of the Plan. Existing land uses are not preempted by the Plan. Flood inundation levels reflect restrictions on land use specifically to minimize loss of property, and to minimize potential danger to the safe and efficient operation of the flood control facility. The latter bears a direct relationship to the location and type of structures allowed within the basin.

12-12 The Plan delineates land use categories "1" through "4c" to reflect low to more intense uses. Compatible uses are provided that reflect both the sensitivities of the selected resources and COE knowledge of uses compatible to a specific frequency of flooding.

12-13 Additional zones delineate habitat area for the least Bell's vireo, which requires minimal disturbance, and delineates the area which would mitigate all adverse effects to the basin as a result of the new flood control construction for the basin.

12-14 Users of the Resource Use Plan map must understand that the map reflects potential compatible uses. This allows for a consideration of a variety of uses, utilizing the Plan map as a guide in the review process. If apparent conflicts in the interpretation of policy arise in the review process, the COE will apply the most restrictive interpretation. Additionally, the COE considers existing uses as "grandfathered" into the Plan. However, any proposed alteration, revision, or expansion of such uses will be subject to review of the compatibility of the proposed change with the Resource Use Plan.

Implementation of the Resource Use Plan

12-15 This report provides the necessary guidelines to review proposals for development or use within Prado Basin. This report also provides a Resource Use Plan map for preliminary evaluation, and provides additional guidelines for specific evaluation, including resource use objectives and information on existing site features.

12-16 When a specific proposal is received for use on Federal lands, the COE will evaluate the proposal using the above mentioned guidelines, and will meet the requirements of the National Environmental Policy Act of 1969 as amended. Any conflicts identified in the review process will be resolved where possible, and a recommendation for approval, modification or disapproval will be made.

12-17 This review process may be considered and applied by county and local planning officials and private developers for proposal for use or development on non-Federal lands within the Reservoir Design Flood zone within the basin.

Conclusions and Recommendations

12-18 This Resource Use Plan provides guidance for the future orderly development of the resources at the Prado Basin. The Plan establishes appropriate locations for high, low or no intensity uses and provides criteria for development. As previously stated, it is not the purpose of this plan to be an absolutely definitive authority that details all specific development features which may be considered in the future. It is recognized that conflicts of land use may arise. In fact, there are potential conflicts with some of the existing land uses which have been "grandfathered" into the Plan. Conflicting land uses, whether currently proposed or to be proposed in the future, will not necessarily be precluded from development, as case by case mitigation measures are developed, approved and implemented to offset any impacts to significant resources. All specific proposals for future development will be evaluated on their merit subsequent to compliance with the National Environmental Policy Act of 1969 and other policy considerations.

12-19 The guidance provided in the Resource Use Plan ensures:

a. The utilization of the plan to serve as a guide for land use planning by the COE staff, county and local planning officials, and private developers.

b. The Plan reflects Federal regulations and policy which minimizes flood damage to property, and protects specific environmental resources.

c. The provision of guidelines for evaluating proposed uses and developments, including resource use objectives, resource element data, including existing land use, flood inundation level constraints, and existing site feature data.

d. The preservation of the flood control integrity of the Prado Basin, and the appropriate consideration of proposed development.

12-20 A subsequent Supplemental General Design Memorandum will be prepared to address site specific recreation plan and prepare the required cost sharing agreements.

12-21 The Prado Basin Resource Use Plan will be used as the basis of orderly development within the Prado Basin.

XIII. ENVIRONMENTAL ANALYSIS

Environmental Impacts

SEDIMENTATION

13-01 Sedimentation behind Prado can be expected to increase. Short-term effects will involve erosion of material from construction sites (borrow areas, levees, etc.,) in the basin. Long-term effects will result from greater inundation-duration frequencies of storm events, which bring in large sediment loads. Sedimentation will occur at higher elevations than in the existing condition.

WATER RESOURCES

Hydrology and Water Use

13-02 The water control plan sets guidelines for greater release rates than previously experienced at Prado. Downstream capability has been increased, so that larger releases can be accommodated. Constraints to releases, such as impacts to downstream users and downstream channel problems, may, at times, require release rates below the average release rates listed in the water control plan. No major impacts to existing water uses will occur. Downstream groundwater recharge would continue at a rate comparable to existing project condition.

Water Quality

13-03 For the most part, little or no adverse impact on water quality is expected. The effect of more days with a pool present, deposition of fine sediments (due to longer settling times), and bacteriological quality changes will be to impact water quality, but overall, these factors are not considered to be significant in the future with project condition. Little or no effect on groundwater quality is expected due to increased storage time. Prado groundwater is discussed in Volume 7, Section XI of the Phase II GDM.

13-04 Sediment liberated due to construction activities, will be washed into the reservoir by rainfall and result in more turbid outflow and increased sedimentation behind the dam. The effect could be significant, affecting in-stream biota in the Santa Ana River canyon and increasing siltation at the Orange County Water District spreading grounds.

AIR QUALITY

13-05 Impacts to air quality will be local and short-term, due to construction activities, and will primarily be associated with vehicle emissions and dust generation. Increased vehicle emissions would result from heavy equipment use on the construction site, trucks hauling borrow materials to the construction site, and from personal vehicles driven by construction workers.

LAND USE AND SOCIAL CONCERNS

Important Farmlands

13-06 The Soil Conservation Service has determined that 1,781 acres of prime farmland are located within the proposed Prado project area. These lands are generally near the upper basin fringes rather than in the bottomlands near Prado Dam.

Recreation

13-07 A Resource Use Plan has been prepared for Prado (Appendix D to Volume 2 - Prado Dam). It serves as a general plan for the future recreation and land use development of Prado, and it also lists some site specific proposed projects, identifying zones for various levels of intensity of recreation development. Although extensive recreation development is contemplated, specific recreation plans at Prado are deferred from this report.

13-08 Impacts to existing recreation in the basin due to construction activities will be minimal. Informal recreation in proposed construction areas may be disrupted.

Growth Inducement

13-09 Growth inducement is not expected to occur as a result of improvements made to the lower river. Currently, the lower river area is rapidly urbanizing in those areas where development can still occur.

TRANSPORTATION AND UTILITIES

Facilities

13-10 The 71 and 91 Freeways, the Serfas Club Drive, Cucamonga Avenue, Pipe Avenue, and Euclid Avenue will be used by project related heavy equipment. The effect is not expected to be significant.

Access

13-11 Access to the project area will be through existing roads in the basin. In order to avoid impacting existing roads, and to shorten traveling time, unpaved roads will be constructed from the borrow areas to the site of structures.

Transport of Borrow Materials

13-12 Haul roads will be built from the borrow areas to the various construction sites. Some local roads will be used when possible. It can be expected that when local roads are used, some impact will be felt by the local community, although traffic volume is not heavy on these roads. Traffic will be heavier, and slow moving heavy equipment will hinder traffic.

NOISE

13-13 The Prado Dam basin is for the most part a quiet rural area, especially in the lower basin, with some human-induced noise present due to the presence of the 91 and 71 Freeways. The project will have local short-term impacts to the environment, as construction-related noise will be present.

BIOLOGICAL RESOURCES

13-14 Three main habitat types are impacted due to construction activities and operation of the future Prado basin: willow woodland, shrubland, and oak woodland. The borrow areas, Highway 71 dike, Alcoa dike, auxiliary dike, haul roads, the outlet works, and the operation schedule will together impact approximately 161 acres of willow woodland. The Highway 71 dike and the outlet works low flow channel will impact approximately 12 acres of shrubland. The Highway 71 dike will impact 5 acres of oak woodland. Aquatic habitat in Prado basin will also be impacted by deposition of fill material in the river channel up to the 470-feet elevation. The haul road from borrow area 2 will impact a portion of the aquatic habitat on Chino Creek. However, impacts to the aquatic resources are not considered significant.

13-15 Planting of native coastal sage scrub and chaparral species at the borrow areas will compensate as mitigation for loss of shrubland habitat.

13-16 Impacts to Canada geese can be compensated by efforts to avoid or minimize impacts, and by efforts to provide suitable foraging areas for the geese. To minimize impacts, the borrow area will be utilized in a controlled manner which will always provide for the availability of foraging habitat. Borrow activities will be scheduled so that at least one section of the borrow area will either be undisturbed, or adequately

restored at the time the geese are present in the basin (i.e., November through February). Restoration will include recontouring, respreading topsoil, fertilization, and seeding. In addition, 60 acres of the borrow area will be mowed annually to allow the geese better access to young shoots.

13-17 Mitigation for the loss of oak woodlands will require the establishment of oak woodlands in an upland area south of Prado Regional Park; this area does not currently support oaks. Experts will be consulted to assess the feasibility of our oak woodland mitigation plan.

13-18 In addition to the above measures to replace oaks, the following measures will be taken to avoid, or minimize where unavoidable, impacts to oaks outside of the dike "footprint":

a. Trees that should be avoided will be flagged.

b. If pruning of some trees is necessary, it will be done by experts to minimize the likelihood of the tree dying.

13-19 In addition, construction activities will be monitored to reduce project impacts on habitat areas peripheral to the borrow areas, and scraped topsoil will be stockpiled in borrow areas and spread over the borrow areas when borrow activities are completed.

Endangered Species

13-20 Although the bald eagle and the peregrine falcon are listed species found in this area, the proposed project will not impact either species. The Santa Ana River project may cause short term, temporary and possibly, some long-term impact to the least bell's vireo and its habitat. Impacts due to changes in the operation schedule will affect about 133 acres of habitat that is suitable for the vireo. The 133 acres include areas that are also impacted due to the construction of haul roads.

13-21 Compensation for the loss of vireo habitat will be accomplished by acquiring and establishing 133 acres of willow woodland with understory at elevation above at least 505 feet and providing approximately $450,000 of project fund for a monitoring program for the vireo nesting activities, fledgling success, bird censuses, etc., and a management program for its predators and for the brown-headed cowbird, a species which parasitizes vireo nests. The U.S. Fish and Wildlife Service will conduct the management and monitoring activities in the basin. The funding will provide for the activities for 10 years or more. The replacement habitat, which will be created prior to construction but will not have to be functional or occupied prior to construction, will be established on Orange County Water District lands which have been mowed and which currently occupied by pheasant hunting operation. Purchase of land will cost $1.33 million. Establishment of this habitat will cost another $655,000.

CULTURAL RESOURCES

13-22 Construction and operation of Prado Dam will affect many significant cultural resources. Utilization of Borrow Area 1 will impact four historic archeological sites which may be eligible for the National Register, and may disturb four others located just outside the limits of the borrow area. Utilization of Borrow Area 2 will impact four other historic sites that have not yet been evaluated for the National Register. Construction of the spillway may disturb the "Spillway Cemetery" if still intact. It was substantially disturbed during the original construction. Approximately 60 cultural resources may be affected by sediment behind the dam, and 56 others may be affected by a variety of other impacts over the life of the project.

13-23 A Programmatic agreement will be negotiated with the State Historic Preservation Officer and the Advisory Council on Historic Preservation. The detailed mitigation plan will be presented in the Cultural Resources FDM. At a minimum, mitigation will consist of data recovery excavations for National Register eligible prehistoric and historic arecheological sites located in the two borrow areas, monitoring of spillway excavations and grading in the area of the "Spillway Cemetery" by a qualified archeologist, historic documentation of the existing Prado Dam; and a program of preservation, relocation, floodproofing, restoration, data recovery, documentation, and interpretation of other significant cultural resources in the basin.

COSTS

13-24 Estimated cost for all items of biological mitigation are the following:

Improvement at borrow area for geese foraging		$43,000
Replacement of Oak Woodland		63,000
Replacement of habitat for vireo		665,000
Monitoring and management for vireo		450,000
	Total Cost	$1,221,000

13-25 The estimated cost for cultural resources mitigation is listed below:

Data Recovery		$4,130,000
Historic Documentation		760,000
Relocations		196,000
Floodproofing		304,000
Sum		$5,390,000
Contingencies (15%)		810,000
	Total Cost	$6,200,000

XIV. DIVERSION AND CONTROL OF WATER DURING CONSTRUCTION

General

14-01 Diversion and control of water would be required during construction of the outlet works, the dike at Corona Sewage Treatment Plant, the low points of the auxiliary dike, the dike at the Alcoa Aluminum Plant, and the dike along the Corona Expressway. The highest water surface ever recorded behind Prado Dam was at elevation 528 in February 1980. The 40-year-frequency flood pool with the water surface at elevation 525 was considered to be a reasonable elevation for deciding the construction schedule of certain structures, and this elevation was also selected as the top elevation for the cofferdam during construction of the outlet works. Construction of the lower portion (below elevation 525) of the dike at Corona Sewage Treatment Plant would be accomplished during the summer dry season. All other construction work would be either on the downstream side of the dam embankment, or on high ground above the 40-year flood pool at elevation 525; therefore, construction of the dam and dike embankments, addition of spillway walls, and modification of the Corona Expressway would not have to be restricted to the dry season. The existing outlet works would remain fully operational and would be utilized for dewatering the reservoir to allow construction of the dike along the Corona Expressway at low elevations.

Outlet Works

14-02 In order to provide protection against 40-year-frequency flood, the existing ground upstream of the outlet works would be maintained at elevation 525. A temporary dike would be constructed at the upstream end of the outlet works where the existing ground is below elevation 525. Construction of the outlet works would be accomplished in three stages. The stages would permit the existing flood control structure to remain in operation through out the construction of the new outlet works. Detailed descriptions of various stages of construction are presented in Section 10 of Appendix C, entitled Outlet Works.

Auxiliary Dike

14-03 During construction of the auxiliary dike water from two different sources would require control and diversion: (1) impounded water in Prado Dam resevoir and (2) local runoff from the 0.8 square miles of drainage area south of the dike. During, construction of the portion of the dike below elevation 575 would be accomplished during the dry summer months. Construction of the remaining parts of the dike above elevation 575 during the winter months would encounter runoffs from the vast drainage area south of the dike and the Santa Fe Railway. Hydraulic studies indicate that a 40-year flood event with the proposed culverts already installed and operational would result in a water surface at elevation 575 on the south side of the dike. With this degree of protection, the remaining dike could be completed during the rainy winter months.

Dike at Corona Sewage Treatment Plant

14-04 Approximately 50 percent of the length of this dike would be located on the existing ground surface below elevation 525. The water surface in the reservoir must be kept below this elevation in order to allow construction during the winter rainy season; otherwise construction must be carried on during the summer. Construction for this dike would require a comparatively small quantity of embankment fill; therefore, it would be prudent to construct the portion of dike below elevation 525 during the summer and avoid the need for extensive diversion and control of water requirements.

Dike Along Corona Expressway

14-05 The toe of the dike along Corona Expressway would be as low as elevation 480 which would be 10 feet below the debris pool. Construction of this portion of the dike during the winter months would be contradictory to the operation policy of the dam. Dewatering of the construction area during the winter months would be expensive, because the area of the toe is within the reservoir pool. The construction of the dike would be accomplished in early summer after the reservoir pool has been lowered to elevation 480.

XV. REAL ESTATE REQUIREMENTS

General

15-01 The Prado Dam and Reservoir are located in San Bernardino and Riverside counties between the cities of Corona, Ontario, Norco, and Chino. The project area is bordered by Kimball Avenue to the north, Hammer Avenue to the east, Riverside Freeway (91) to the south, and Corona Expressway (Highway 71) to the west. The reservoir occupies an area of 9,636 acres between the bottom of reservoir at elevation 465 and adjacent hills up to elevation 900 on the west side of the Corona Expressway. This project land was acquired in the 1940's when the value of lands were comparatively low and more than adequate amount of lands were taken for the flood control project. However, the guideline was to acquire all lands up to elevation 543 in fee title and lands above elevation 543 were obtained as flowage easement. As a result, 6,577 acres were obtained in fee title and 3,059 acres were acquired as flowage easement.

15-02 Within the existing Prado Basin there are several parks, a golf course, an airport for small aircraft, 13 oil and gas wells, the Corona sewage treatment plant, and the Rincon cemetery. Most of the basin is undeveloped and contains natural wooded wetland used by migratory birds and a wide variety of small animals. The cemetery was established before 1888 when the first burial documented by official records began. The cemetery is within the basin but on high ground between elevations 525 and 540, and has never been inundated by flood waters since Prado Dam was built. The chance that the cemetery would be flooded is very remote.

Lands to be Acquired

15-03 Most of lands in the basin, and its immediate surrounding are zoned for agriculture or related agriculture uses with some residential and planned unit development. The land to be acquired for the proposed project is primarily in agriculture related activities such as feed lot,

dairies, horse ranches, irrigated fields, and truck crops. The surrounding agricultural area is the major milkshed for metropolitan southern California. The dairies are the feed lot type with the cows confined to corrals on loafing barns, but practically all the feed is imported from outside the area. The investment in houses, barns, and other facilities for dairy farm operation is substantial. Residential and industrial development is rapidly encroaching on the perimeter of the project area. The demand for residences is strong with new subdivisions being built or planned in the general area.

15-04 Due to the recommended enlargement of the reservoir and raising the spillway crest from elevation 543 to 563, the existing flowage easement between elevations 543 and 556 would be kept; and an additional 1,661 acres of which some in fee title and the remaining in flowage easement between elevations 556 feet and 566 feet would be acquired for the reservoir. The guide taking line at elevation 566 was determined in accordance with EP 405-1-12, and is in compliance with the authorizing law of the project.

15-05 The California Institute For Women, the Corona National Housing Tract, and an Alcoa Aluminum Plant are located in the perimeter of the project area; and a dike is planned to protect each facility. An auxiliary dike would be built on the east side of the spillway near its crest extending to the east side of Serfas Club Drive for total distance of approximately 1 mile and occupying an area of approximately 36 acres. Another dike would be required along Highway 71 on the west side of the basin for preventing flood waters from escaping the reservoir. Fee title land would be acquired for dike and floodwall structures.

5-06 Approximately 280 tracts of land lie within the 1,661 acres to be taken in fee title and flowage easements. Farms and dairies represent the greatest group in the project area with 85 affected. Also, 64 residences will be affected by the taking. The balance of properties is represented by a variety of different uses. The highest and best use of the various types of property in the area, in most cases, would be the current use and it is assumed to be the most profitable use considering current conditions and the location of the land.

15-07 The estimated cost of real estate of Prado Basin Expansion is:

Land Value	$52,502,000
Improvements	23,646,000
Equipment	3,875,000
Damages	10,477,000
Contingencies	20,788,000
Relocation (PL 91-646)	1,115,000
Administrative Costs	2,541,000
Sum	$114,944,000
Biological Mitigation Land	1,330,000
Total Cost	$116,274,000

Acquisition

15-08 In accordance with the authorizing document, the local sponsoring agency would be responsible for acquisition and bearing all costs in connection with the additional land required for the project. Fee title land would be acquired prior to construction of structures, and reservoir easement would be obtained prior to initiation of raising the spillway.

XVI. COST ESTIMATES

First Cost

16-01 The estimated first cost (table XVI-1) of the recommended enlargement of Prado Dam and reservoir for flood control is $212,623,000 (October 1987 price level) of which $116,274,000 would be for acquisition of rights-of-way and easements. Earthwork quantities were derived from topographic maps which were based on an aerial survey conducted during July and August of 1979, and unit prices were developed by using the latest quotes from local supplier and latest construction prices for similar kinds of work in southern California. Required borrow for construction of dam and dike embankments would be obtained from borrow areas within the reservoir owned by the U.S. Government; any unsuitable material except organic material would be disposed of at the borrow sites. Stone and concrete would be obtained from existing commercial sources from nearby quarry and concrete plant. Unit prices were then projected to the midpoint of construction period which is scheduled to last 36 months. In accordance with the EM 1110-2-1301, a 15 percent contingency was added to the estimated construction cost. The percentage of construction costs that were used for engineering and design, as well as supervision and administration are based on prevailing rates experienced by the Los Angeles District Office. Cost for real estate was based on appraised market value of lands and easement around the Prado Dam reservoir. The cost for relocation of highway, street, and utilities were based on information supplied by the owners of such facilities.

Operation and Maintenance

16-02 Responsibility for operation and maintenance of Prado Dam and reservoir can be divided into three categories: (a) daily operation of the flood regulating gates and hydrologic facilities; (b) repair all flood control facilities such as dikes, outlet works, etc.; and (c) maintenance of Prado Dam reservoir as an important wildlife habitat area including periodic coordination with other governmental agencies.

The Federal Government would be obligated for the cost for the operation and maintenance of the existing facilities, while the local sponsoring agencies would be delegated to pay for operation and maintenance for the modified portion of the flood control project.

Table XVI-1. Summary of First Costs. (October 1987 Price Level).

Acc't No.	Description	Amount
	Flood Control Construction -	
02	Relocations	$692,000
03	Reservoir	58,000
04	Dams	68,693,000
18	Cultural Resources Mitigation	6,200,00
20	Permanent Operating Equipment	129,000
30	Engineering and Design	5,304,000
31	Supervision and Administration	4,546,000
51	O&M Manual, and Water Control Plan	250,000
	Total Construction	$85,872,000
	Lands and Relocations -	
	Lands and Damages	$116,274,000
	Relocations, Roads and Utilities	5,680,000
	Total Lands and Relocations	$121,954,000
	Pre-construction Engineering and Design	4,797,000
	Total, Flood Control First Cost -	$212,623,000

Table XVI-2. Detailed Estimates of First Cost.
(October 1987 Price Level).

Acc't No.	Description	Quantity	Unit	Unit Price	Subtotal
	Flood Control Costs - Construction:				
02	Relocation, Utilities				
	30-inch gas line	1	Job	L.S.	$250,000
	Other Underground Utilities	1	Job	L.S.	352,000
03	Reservoir:				
	Clearing Debris	1	Job	L.S.	50,000
04	Dam:				
	Mobilization and Preparatory Work	1	Job	L.S.	750,000
.1	Diversion and control of water	1	Job	L.S.	1,000,000
	Clear and Remove Obstructions	1	Job	L.S.	500,000
	Dam Embankment:				
	Fill, Compacted, Zone I	458,000	CY	$4.00	1,832,000
	Fill, Compacted, Zone II	803,000	CY	4.00	3,212,000
	Bedding Material	13,000	Ton	20.00	260,000
	Filter Material	9,000	Ton	20.00	180,000
	Riprap on U.S. Slope	34,000	Ton	23.00	782,000
	Gravel on D.S. Slope	27,000	CY	30.00	810,000
	Access Ramps	1	Job	L.S.	238,000
	Asphalt Pavement	1,200	Ton	48.00	58,000
	Floodwall	1	Job	L.S.	66,000
	Modification of Drain Structure	1	Job	L.S.	131,000
	Plug of Existing Outlet	1	Job	L.S.	37,000
.3	Outlet Works	See Appendix B			26,707,000
.5	Modification of Spillway:				
	Excavation	4,400	CY	4.00	18,000
	Backfill	3,200	CY	5.00	16,000
	Removal of Existing Invert	5,400	CY	CY	383,000
	Sawcut 12-inch Notch	1	Job	L.S.	50,000
	Concrete, Invert and Ogee	34,000	CY	75.00	2,550,000
	Concrete, Slab	750	CY	75.00	56,000
	Concrete, Retaining Wall	1,100	CY	138.00	151,000
	Concrete, Training Wall	600	CY	138.00	83,000
	Concrete, Trapezoidal Wall	1,600	CY	130.00	208,000
	Cement	212,000	Cwt	5.00	1,060,000
	Steel, Reinforcing	4,500,000	Ton	0.42	1,890,000
	Water Stop	2,600	LF	14.00	36,000
	Subdrain	1	Job	L.S.	11,000
	Replace Chain Link Fence	2,100	LF	12.00	25,000

Table XVI-2. (Continued)

Acc't No.	Description	Quantity	Unit	Unit Price	Subtotal
.5	Auxiliary Dike:				
	Excavation, Foundation	75,000	CY	3.00	$ 225,000
	Fill, Compacted,	619,000	CY	2.00	1,238,000
	Concrete, Floodwall	2,100	CY	203.00	426,000
	Cement	12,000	Cwt	5.00	60,000
	Steel	130	Ton	840.00	109,000
	Culvert, 36-inch RCP	570	LF	90.00	51,000
	Culvert, 72-inch RCP	1,130	LF	218.00	246,000
	Culvert, 82-inch RCP	210	LF	312.00	66,000
	Inlet Structures	1	Job	L.S.	53,000
	Outlet Structures	1	Job	L.S.	150,000
	Catch Basin at Sta. 12+00	1	Job	L.S.	15,000
	Riprap	50,000	Ton	21.00	1,050,000
	Gravel Drain	21,000	CY	25.00	525,000
	Asphalt Pavement	2,100	Ton	48.00	101,000
	Bedding Material	17,000	Ton	18.00	306,000
	Filter Material	12,000	Ton	18.00	216,000
	Dike Along Highway 71:				
	Clear Site	15	AC	2,500	38,000
	Stripping and Excavation	24,000	CY	3.00	72,000
	Fill, Compacted	632,000	CY	4.00	2,528,000
	Riprap	27,000	Ton	21.00	567,000
	Bedding Material	10,000	Ton	18.00	180,000
	Filter Material	6,800	Ton	18.00	122,000
	Dike at Corona Sewage Treatment Plant:				
	Clear Site	14	AC	2,500	35,000
	Excavation, Foundation	40,000	CY	3.00	120,000
	Fill, Compacted	544,00	CY	2.00	1,088,000
	Culvert, 36-inch RCP	1	Job	L.S.	56,000
	Riprap, 18-inch	33,000	Ton	21.00	693,000
	Filter Cloth	46,000	SY	2.00	92,000
	Dike at Alcoa Aluminum Plant:				
	Clear Site	13	AC	2,500	33,000
	Excavation, Foundation	38,000	CY	3.00	114,000
	Fill, Compacted	311,000	CY	3.00	933,000
	Culvert, 36-inch RCP	1	Job	L.S.	35,000
	Riprap, 18-inch	28,500	Ton	21.00	599,000
	Filter Cloth	44,000	SY	2.00	88,000
	Sand Drain	5,700	CY	16.00	91,000

Table XVI-2. (Continued)

Acc't No.	Description	Quantity	Unit	Unit Price	Subtotal
.5	Dike at Corona National Housing Tract:				
	Clear Site	5	AC	2,500	$13,000
	Excavation, Foundation	12,000	CY	3.00	36,000
	Fill, Compacted	84,000	CY	4.00	336,000
	Culvert, 36-inch RCP	1	Job	L.S.	28,000
	Riprap, 18-inch	9,000	Ton	21.00	189,000
	Filter Cloth	13,000	SY	2.00	26,000
	Concrete, Floodwall	630	CY	223.00	140,000
	Cement	3,600	Cwt	5.00	18,000
	Steel, Reinforcing	76,000	Lb.	0.42	32,000
	Dike at California Institution for Women:				
	Clear Site	12	AC	2,500	30,000
	Excavation, Foundation	40,000	CY	3.00	120,000
	Fill, Compacted	231,000	CY	3.00	693,000
	Culvert, 36-inch RCP	1	Job	L.S.	30,000
	Riprap, 18-inch	25,000	Ton	21.00	525,000
	Filter Cloth	29,000	SY	2.00	58,000
	Esthetic Treatment	See Page XI-3			978,000
	Biological Mitigation	See Page XIII-5			1,062,000
18	Cultural Resources Mitigation	See Page XIII-5			5,390,000
20	Permanent Operating Equipment	1	Job	L.S.	102,000
	Double Garage with Office	1	Job	L.S.	10,000
	Sum:				65,889,000
	Contingencies (15%):				9,883,000
	Subtotal:				$75,772,000
30	Engineering and Design (7.0%)				5,304,000
31	Supervision and Administration (6.0%)				4,546,000
51	Operation and Maintenance Manual	1	Job	L.S.	100,000
	Water Control Plan	1	Job	L.S.	150,000
	Total, Construction Cost:				$85,872,000

Table XVI-2. (Continued)

Acc't No.	Description	Quantity	Unit	Unit Price	Subtotal
	Lands and Damages:				
	Land Above Elev. 556	See page XV-4			$116,274,000
	Modification of Corona Expressway	1	Job	L.S.	2,829,000
	Modification of Pomona-Rincon Rd	1	Job	L.S.	100,000
	Modification of Clearwater Drive	1	Job	L.S.	170,000
	Modification of Smith Avenue	1	Job	L.S.	39,000
	Modification of Butterfield Drive	1	Job	L.S.	135,000
	Modification of Rincon Road	1	Job	L.S.	294,000
	Modification of Auburndale Street	1	Job	L.S.	67,000
	Transmission Power Lines	1	Job	L.S.	2,000,000
	Utilities, Overhead	1	Job	L.S.	46,000
	Subtotal, Land and Damages:				121,954,000
	Pre-construction Engineering and Design				4,797,000
	Total, Flood Control First Cost:				$212,623,000

Comparison of Estimates

16-03 A tabulation of the estimated first costs for flood control as presented in the Phase I General Design Memorandum (GDM), the updated Phase I GDM estimate, and the present estimates are shown in table XVI-3. The updated estimate is based on the Phase I GDM design and cost estimate except that the cost has been escalated to the price level of the October 1987. The differences in project costs between the updated Phash I GDM and the present estimate are explained in the following paragraphs:

a. The addition of $602,000 is due to the change in the authorizing law in which the relocation of underground utilities is considered a project cost.

b. The addition of $50,000 for reservoir clearing is due to the fact that this item was not separately identified in the Phase I GDM cost estimate.

c. The decrease of $68.9 million in construction cost of the dam is attributable to: (1) a change of contingencies from the 25 percent in the PB-3 to 15 percent for the present estimate which results in reduction of $18.2 million, (2) elimination of upstream toe modification for the dam resulting in decrease of $3.4 million, (3) improved design of the outlet works resulting

in cost decrease of $13.1 million, (4) elimination of widening of the spillway which decreases the construction cost by $38.2 million, (5) realignment of the auxiliary dike to high ground resulting a decrease of $2.4 million, (6) a change in the design of Corona Expressway which would require a dike at Highway 71 resulting an additional cost of $3.5 million, (7) addition of a dike at the Corona National Housing Tract, and refinement of the dike design resulting in cost increase of $4.7 million, (8) reduction in the scope of esthetic treatment results for a cost decrease of $1.7 million, and (9) addition of biological mitigation resulting in cost increase of $1.06 million.

d. The increase of $5.4 million for cultural resources mitigation is due to detailed evaluation of the project which indicates mitigation is necessary.

e. The addition of $112,000 for permanent operating equipment is the result of separating this item from the total cost for the dam.

f. The decrease of $7.2 million in engineering and design (not including $4.8 million of pre-construction E and D) is due to: (1) a change in the percentage of construction cost for engineering and design from 10 to 7 percent, and (2) reduction in total construction costs.

g. The decrease of $3.7 million in supervision and administration cost is due to reduction of total construction costs.

h. The increase of $250,000 for operation and maintenance is due to the addition of this item for preparation of an operation and maintenance manual, including a water control plan.

i. The decrease of $19.6 million in the cost for land and damages is mainly due to (1) the elimination of acquiring properties at the Corona National Housing Tract, and (2) change in the recommendation of acquiring flowage easement instead of fee title land for the reservoir.

j. The decrease in cost of $7.9 million for modification of Corona Expressway is the result of design change.

k. The increase of $1.26 million for modification of streets and relocation of utilities is due to refinement of cost estimate.

Table XVI-3. Comparison of First Costs.

Acc't No.	Item	Phase I GDM (Oct 1979)	Phase I GDM Estimate (Oct 1987)	Present Estimate (Oct 1987)
02	Relocation, Utilities	---	---	$602,000
03	Reservoir Clearing	---	---	50,000
04	Dam	$92,003,000	137,300,000	69,618,000
	Contingencies	(18,802,000)	(28,059,000)	(9,883,000)
.1	Main dam	(8,890,000)	(13,267,000)	(9,856,000)
.3	Outlet works	(26,692,000)	(39,834,000)	(26,707,000)
.5	Spillway	(29,980,000)	(44,740,000)	(6,537,000)
.5	Auxiliary dike	(4,840,000)	(7,223,000)	(4,837,000)
.5	Dike along Hwy 71	(---)	(---)	(3,507,000)
.5	Interior dikes	(1,023,000)	(1,527,000)	(6,251,000)
	Esthetic Treatment	(1,776,000)	(2,650,000)	(978,000)
	Biological Mitigation	(---)	(---)	(1,062,000)
14	Recreation Facilities	13,149,000	**	(---)
18	Cultural Resources Mitigation	(---)	(---)	5,390,000
20	Permanent Operating Eqpmnt	(---)	(---)	112,000
30	Engineering and Design	9,229,000	12,500,000	5,304,000
31	Supervision and Admnstrt	6,460,000	8,210,000	4,546,000
51	O&M Manual and Water Control Plan	(---)	(---)	250,000
	Total, Construction Cost	$121,124,000	$158,010,000	$85,872,000
	Lands and Damages	$91,300,000	$135,840,000	$116,274,000
	Relocations:			
	Modification of Corona Expressway	7,233,000	10,770,000	2,829,000
	Modification of Streets	(---)	(---)	805,000
	Transmission Power Lines	(---)	(---)	2,000,000
	Other Utilities	1,072,000	1,590,000	46,000
	Total Lands and Relocations	$99,605,000	$148,200,000	$121,954,000
	Pre-construction E&D	(---)	(---)	4,797,000
	Total, Flood Control First Cost	$220,729,000	$306,210,000	$212,623,000

**Recreation facilities recommended in Phase I GDM are not included in the updated estimate.

XVII. DESIGN AND CONSTRUCTION SCHEDULE

Feature Design Memoranda

17-01 Feature Design Memorandum will be prepared for the spillway, outlet works, and cultural resources. The schedule for preparation of feature design memorandum would depend on fiscal year funding prior to implementation of a plan or construction of a particular feature.

Supplement to Phase II GDM

17.02 A supplemental Phase II GDM and Environmental impact Statement would be prepared for recreation development within the Prado Dam basin.

Topographic Survey

17-03 Topographic maps for this report were made in July and August of 1979 and these maps would be more than 10 years old by the time of preparation of contract drawings. In general, the terrain within reservoir area owned by the U.S. Government would not change significantly over the next 10 or 15 year period; but deposition of debris on the reservoir bottom and continuous construction activities going on in the fringe area of the reservoir would alter the reservoir capacity and would affect the terrain of areas where proposed flood control facilities would be located. A complete survey of the reservoir area would be made approximately three years prior to initiation of preparing contract plans and specifications.

Preparation of Plans and Specifications

17-04 Preparation of contract plans and specifications for construction would be initiated about 24 months prior to advertising the contract for bids. Construction of all flood control features for Prado Dam would be included in one contract unless fiscal year funding restricts the scope of work.

Construction Schedule

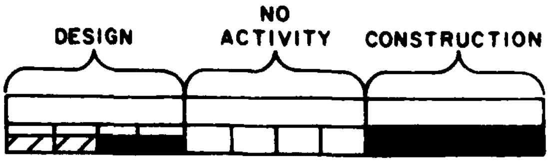
17-05 Construction of all flood control features at Prado Dam is scheduled to last over a 3 year period due to complexity of the work and possible restriction by fiscal year funding. In general, construction of the outlet works, the auxiliary dike and the dike along Highway 71 would be initiated in the first year and completed by the end of second year; construction of the dam embankment, all interior dikes and modification of the Corona Expressway would be started in the second year; and alteration of the spillway would be done during the third year.

Total Funds Required by Fiscal Years

17-06 Total funds which will be required for the preparation of contract plans and specifications and for construction are shown in table XVII-1. The breakdown by fiscal year of the Federal and non-Federal share is presented in the Main Report.

LINE NO	UNIFORM COST CLASSIFICATION	FEATURE ITEMS	PROJECT COST ESTIMATE *	TOTAL AS OF
1	02	Relocations, Underground Utilities	692	
2	03	Reservoirs	58	
3	04	Dams	68,693	
4	.1	Main dam	(11,334)	
5	.3	Outlet works	(30,713)	
6	.5	Spillway	(7,517)	
7	.5	Auxiliary dike	(5,562)	
8	.5	Dike along Hwy 71	(4,033)	
9	.5	Dike at sewage treatment plant	(2,397)	
10	.5	Dike at Alcoa Aluminum plant	(2,177)	
11	.5	Dike at National Housing Tract	(940)	
12	.5	Dike at Institution for Women	(1,674)	
13		Esthetic treatment	(1,125)	
14		Biological mitigation	(1,221)	
15	18	Cultural resource mitigation	6,200	
16	20	Permanent operation equipment	129	
17	30	Engineering and design	5,304	
18	31	Supervision and administration	4,546	
19	51.22	Operation and Maintenance Manual		
20		including water control plan	250	
21		Total Construction Cost	85,872	
22				
23		Lands and damages	116,274	
24		Relocations, roads and utilities	5,680	
25		Preconstruction E & D	4,797	
26				
27		Total flood control first cost	212,623	

*FUNDS IN THOUSANDS OF DOLLARS



SPL FORM 1 NOV 72 571

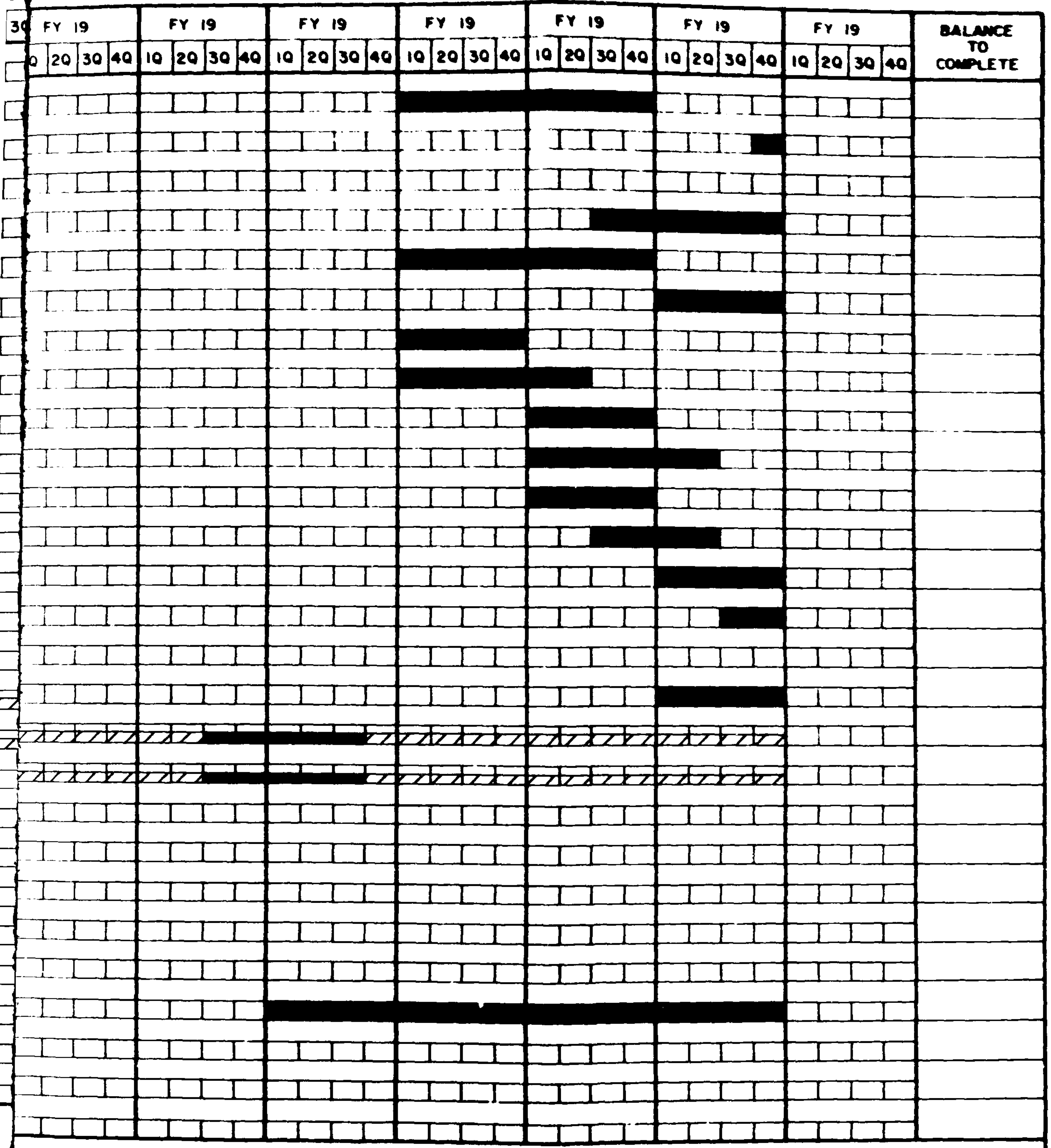


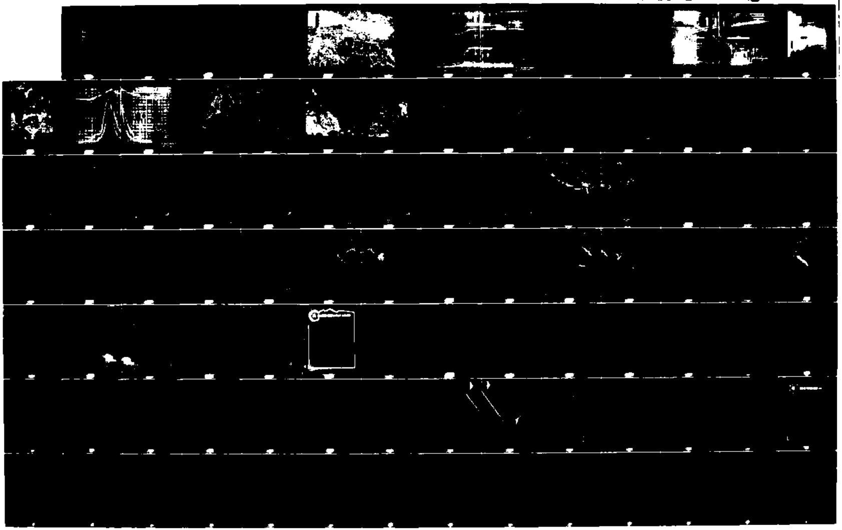
TABLE XVII-1
PRADO DAM
DESIGN AND CONSTRUCTION SCHEDULE

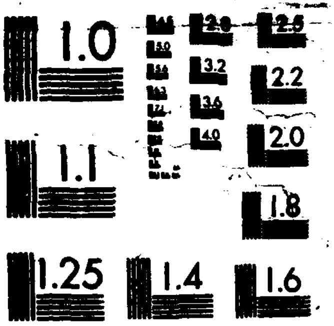
U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS
TO ACCOMPANY DESIGN MEMORANDUM NO.
DATED SHEET 1 OF 1

2

AD-A204 542 SANTA ANA RIVER DESIGN MEMORANDUM NUMBER 1 PHASE 2 GDM 2/10
ON THE SANTA ANA R..(U) ARMY ENGINEER DISTRICT LOS
ANGELES CA AUG 88

UNCLASSIFIED F/G 13/2 NL





MICROC

XVIII. OPERATION AND MAINTENANCE

18-01 After construction of the flood control improvements, an operation and maintenance (O&M) manual would be prepared in accordance with ER 1130-2-304 "Project Operations", and applicable provisions of ER 1150-2-301 "Local Cooperation". The estimated cost of preparing the O&M manual is $100,000. In this manual, the O&M requirement will be specified by the Corps with a determination as to who will perform this task.

18.02 Determination of the Federal and local sponsor share of the O&M costs is based on the condiiton that the Federal Government is responsible for the operation and maintenance of the existing Prado Dam, and the local sponsor would be responsible for the maintenance of proposed modifications.

18-03 Under the esthetic treatment program, the construction contractor would be responsible for irrigation, maintenance, and replacement of planted materials for the initial 90 days. Upon acceptance of the completed structures, the U.S. Army Corps of Engineers and the local sponsoring agencies will divide the responsibilities of maintenance of the planted material in accordance with paragraph 18-05.

18-04 The Annual Report of the Chief of Engineers for FY-1941 indicates that Prado Dam was completed May 1941, and total cost of new work was $6,045,928, rights-of-way cost was $2,129,604, and the cost of maintenance was $3,522. The maintenance cost includes repairs, salary for the dam tender, and administration. In order to provide a frame of reference, the historical O&M costs of the existing Prado Dam were evaluated by using the annual maintenance costs from 1941 to 1987, and an initial construction cost of $6,046,000 (1941 price level). Over the period of past 47 years, the average operation and maintenance cost was 0.30 percent of the price-level escalated construction costs. In addition, the actual O&M costs from 1980 to 1987 have averaged approximately $370,000 annually. These historic costs are only presented as a frame of reference for the following estimated costs.

18-05 An estimate of the O&M costs is made by assuming that the mechanical and electrical equipment needs to be replaced after 50 years at a cost of $2,800,000, resulting in an annual cost of $4,000. Operation and maintenance costs related to the outlet works were obtained from Appendix C, Outlet Works. The maintenance costs (not including salary and administration) for the dam, spillway and ring dikes were based on 0.2 percent of the estimated cost of construction. Other major items of operation and maintenance, and the estimated annual cost for the existing project and the modified project are as follows:

Table XVIII-4. Estimated Annual Operation, Maintenance and Replacement Costs.

Item	Existing Prado Dam	Modified Prado Dam
Operation and Adminstration		
*General Operation	$93,000	$93,000
*Inspection and Evaluation Including Water Quality Monitoring and Reservoir Regulation	33,000	33,000
Maintenance		
*General	6,000	6,000
Dam and Spillway	183,000	227,000
Dikes	---	22,000
Ring Dikes	---	16,000
*Mechanical	15,000	15,000
*Electrical	8,000	8,000
*Debris Removal	5,000	5,000
Esthetic Treatment	---	15,000
Major Replacement		
Mechanical and Electrical Equipment (50-year life)	4,000	4,000
Total	$347,000	$444,000

*See Appendix C, Outlet Works.

It should be noted that the above annual O&M cost does not include cost for biological mitigation which is a project first cost over approximately the first ten years of the project life. From the above estimates, the Federal share would be $347,000 (78.2%) and the local share $97,000 (21.8%).

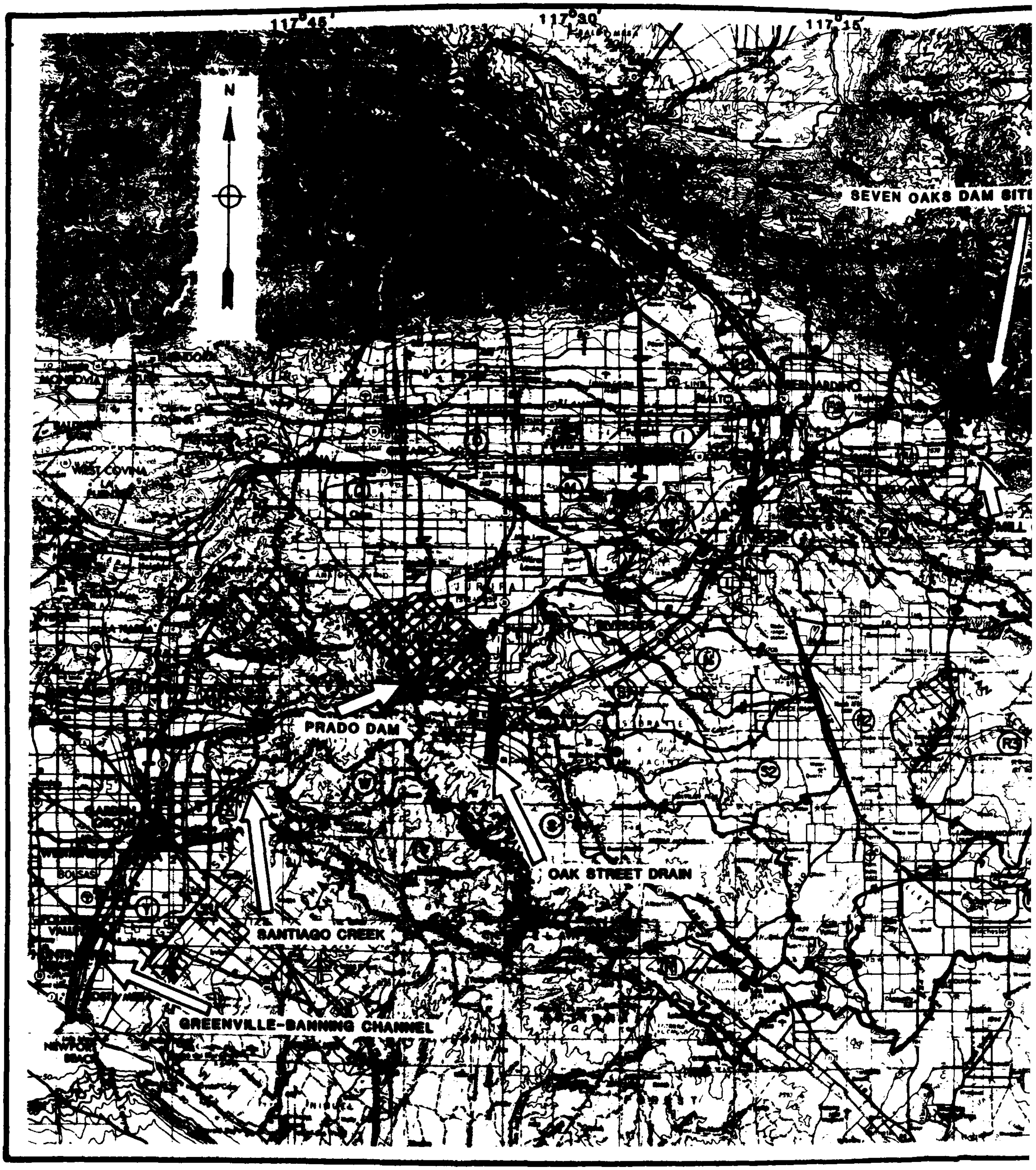
XIX. RESERVOIR REGULATION

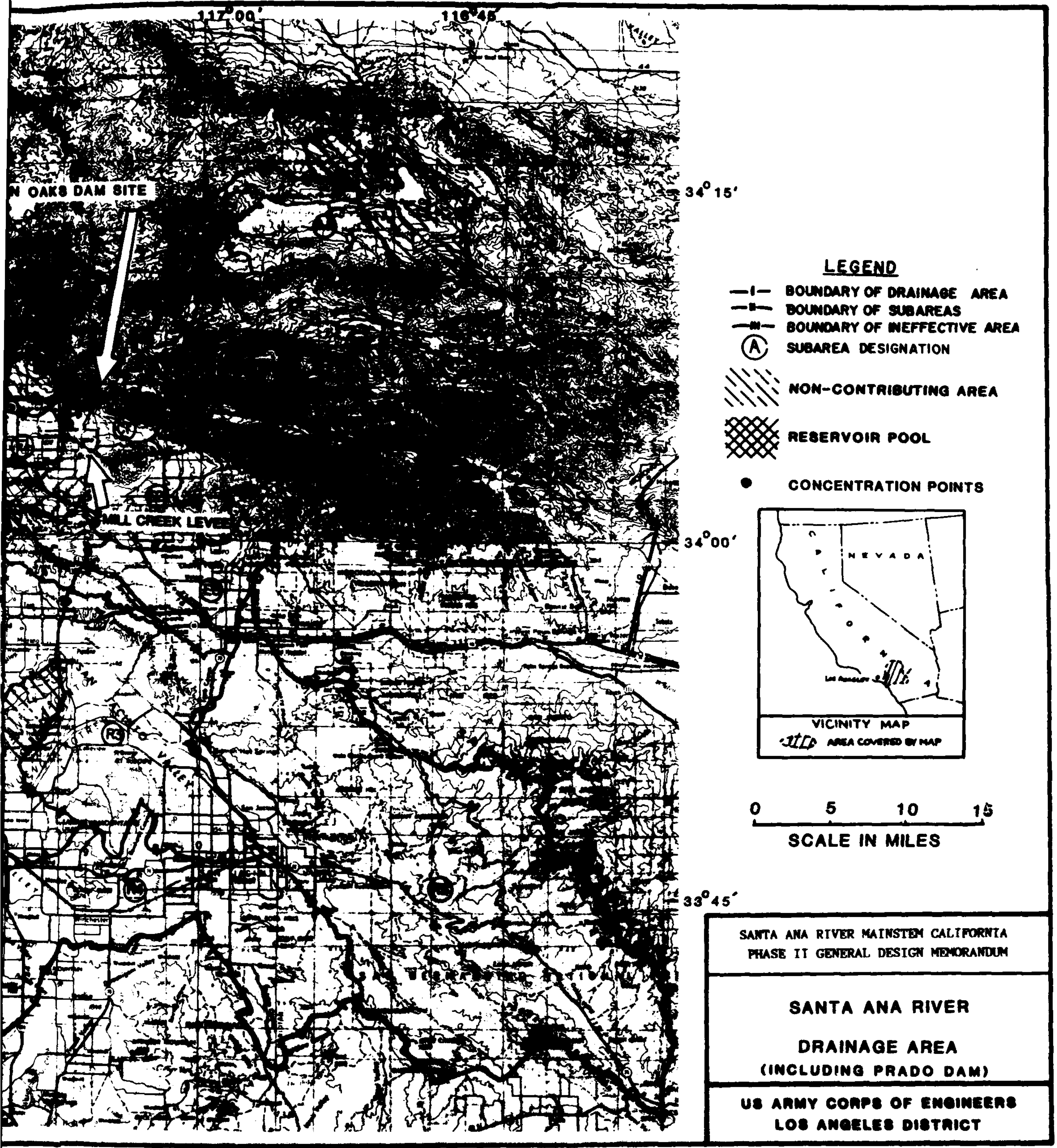
19-01 Storage allocations for the reservoir behind Prado Dam below spillway crest are as follows: flood control storage, 292,000 acre-feet and 100-year sediment storage, 70,000 acre-feet. Prado Reservoir will be used to control discharge in the Santa Ana River from the dam to the Pacific Ocean so that outflow from Prado Dam when combined with runoff from the drainage area downstream of the dam will not exceed the design discharge capacity of the Lower Santa Ana River at any location.

19-02 A debris pool elevation of 490 feet NGVD will be used to submerge the inlet structure. Until the debris pool elevation is exceeded, releases from Prado Dam will be made in coordination with local groundwater recharge operations downstream of the dam.

19-03 Once the debris pool elevation is reached during a flood event, the basic criteria for regulation of Prado Dam is to incrementally increase releases, as needed, to as much as the maximum flow rate of 30,000 ft^3/s in order to evacuate the reservoir in preparation for the next flood event. However, controlled releases should not cause or contribute to downstream flooding. The actual release rate from Prado Dam will be determined after consideration of a number of upstream and downstream watershed conditions. These conditions include time of the year, rainfall and runoff from the upstream watershed, activities in and conditions of the downstream channel, rainfall and runoff in the downstream watershed, and current and forecasted reservoir inflow, outflow and storage. Stream and rainfall gauges in the Santa Ana River drainage area should also be used when determining the proper release rate from Prado Dam.

19-05 Regulation of Prado Dam and Reservoir will be in accordance with the water control plan and manual to be prepared by the Los Angeles District upon completion of the project construction. Water control plans developed by the District will be in general accordance with the basic flood control criteria described in paragraph 19-01 above. Additional information on Prado Dam reservoir regulation can be found in the Hydrology Appendix.


117°45'
117°30'
117°15'
N
SEVEN OAKS DAM SIT
MONROVIA
WEST COVINA
PRADO DAM
OAK STREET DRAIN
SANTIAGO CREEK
GREENVILLE-BANNING CHANNEL
NEWPORT BEACH



SANTA ANA RIVER MAINSTEM CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

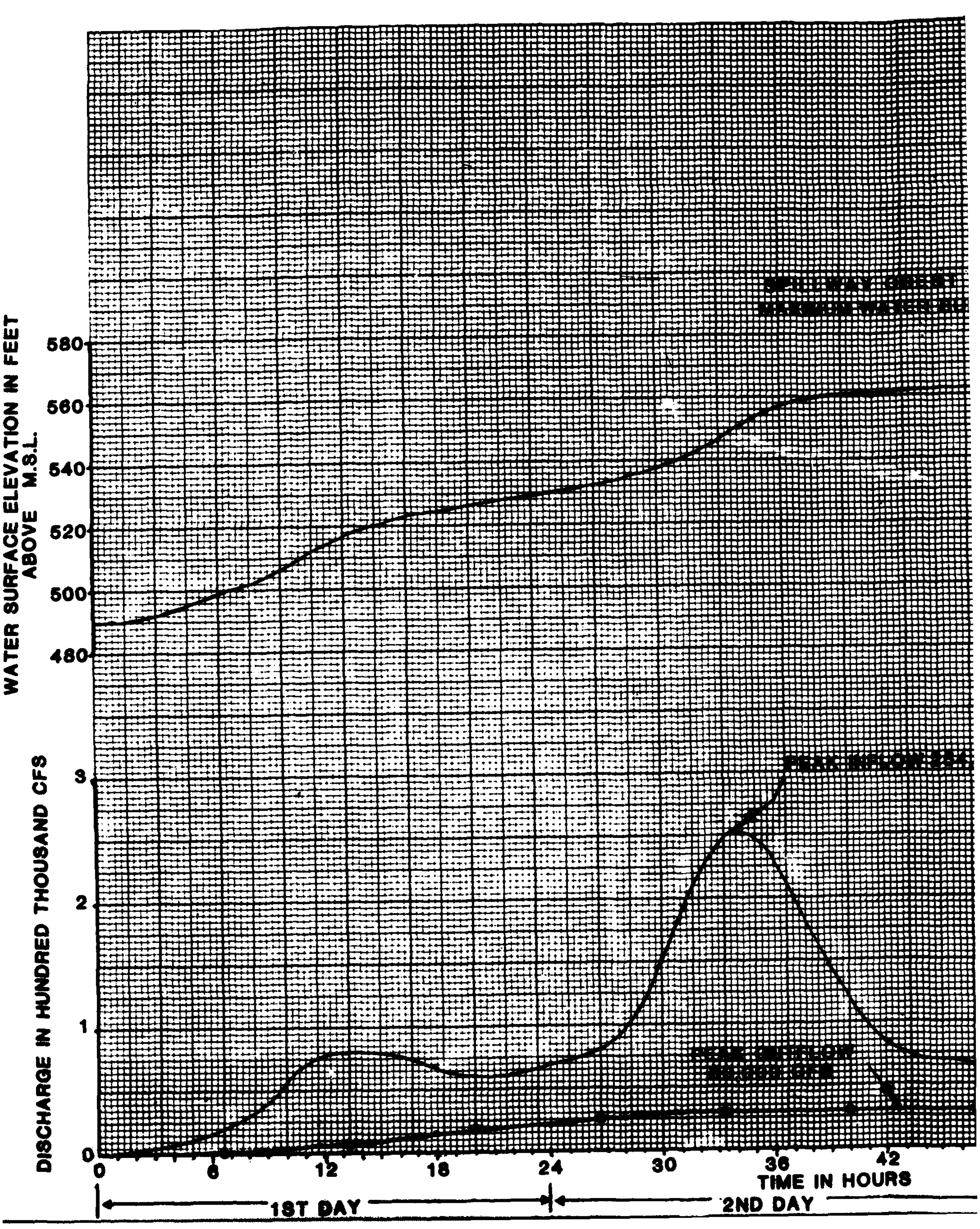
SANTA ANA RIVER

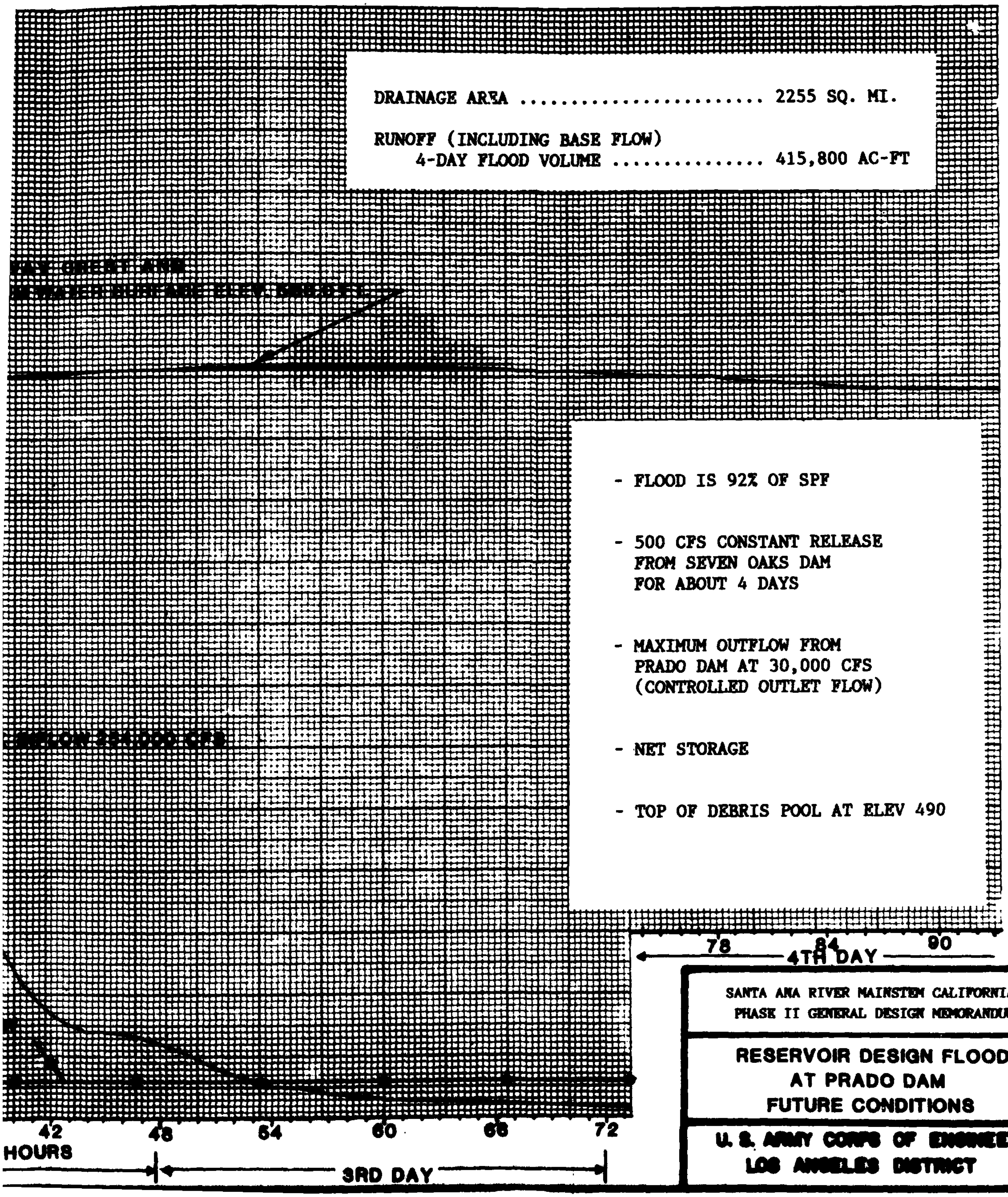
DRAINAGE AREA
(INCLUDING PRADO DAM)

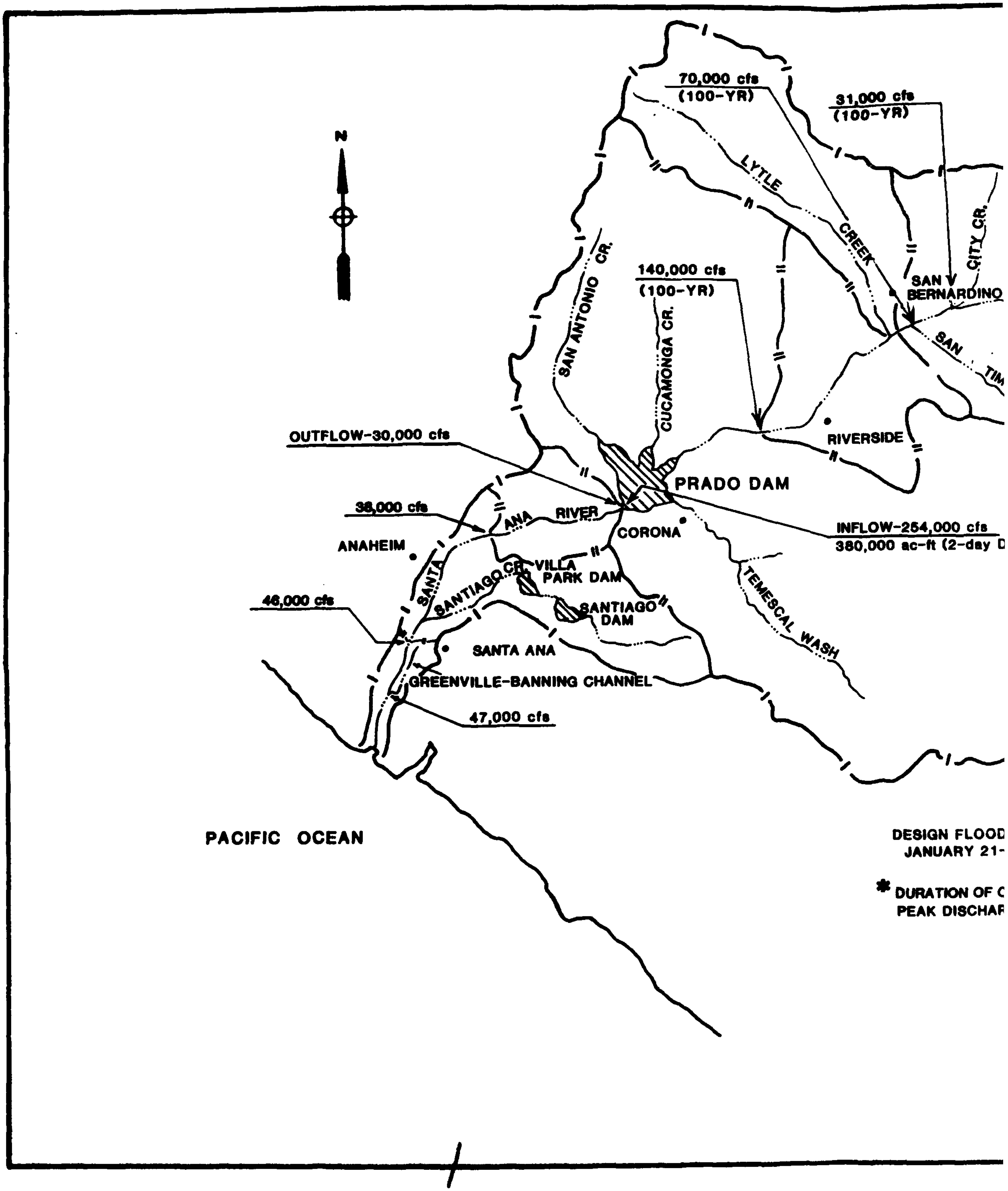
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

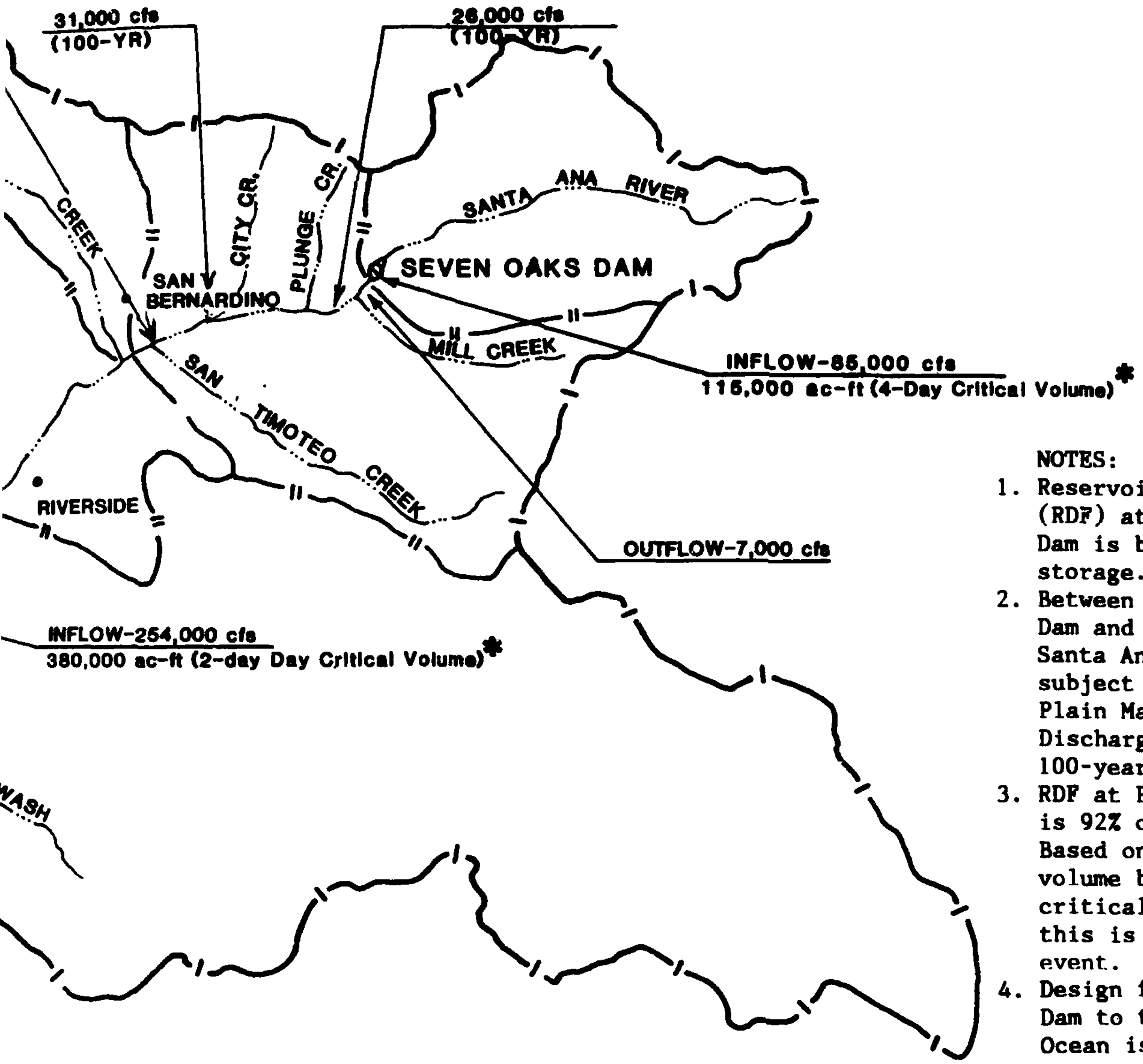
FIGURE IV-1

1 2


SPILLWAY CREST
MAXIMUM WATER SU
WATER SURFACE ELEVATION IN FEET ABOVE M.S.L.
580
560
540
520
500
480
PEAK INFLOW 29
PEAK OUTFLOW
CFS
DISCHARGE IN HUNDRED THOUSAND CFS
3
2
1
0
0
6
12
18
24
30
36
42
TIME IN HOURS
1ST DAY
2ND DAY




N
70,000 cfs
(100-YR)
31,000 cfs
(100-YR)
LYTLE
CREEK
CITY CR.
SAN ANTONIO CR.
140,000 cfs
(100-YR)
CUCAMONGA CR.
SAN
BERNARDINO
SAN
TIM
RIVERSIDE
OUTFLOW-30,000 cfs
PRADO DAM
38,000 cfs
SANTA
ANA
RIVER
CORONA
INFLOW-254,000 cfs
380,000 ac-ft (2-day D
ANAHEIM
SANTIAGO CR.
VILLA
PARK DAM
SANTIAGO
DAM
TEMESCAL WASH
46,000 cfs
SANTA ANA
GREENVILLE-BANNING CHANNEL
47,000 cfs
PACIFIC OCEAN
DESIGN FLOOD
JANUARY 21-
* DURATION OF C
PEAK DISCHAR



NOTES:

1. Reservoir Design Flood (RDF) at Seven Oaks Dam is based on NED storage.
2. Between Seven Oaks Dam and Prado, the Santa Ana River is subject to Flood Plain Management. Discharges are 100-year frequency.
3. RDF at Prado Dam is 92% of SPF. Based on 2+ day volume being the critical duration, this is a 190-year event.
4. Design flood from Prado Dam to the Pacific Ocean is a 190-year event.

DESIGN FLOOD BASED ON OCCURENCE OF JANUARY 21-24, 1943 GENERAL STORM.

* DURATION OF CRITICAL VOLUME IS THAT WHICH GENERATED PEAK DISCHARGE AND WATER SURFACE ELEVATION

SCALE IN MILES

5 0 5 10

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

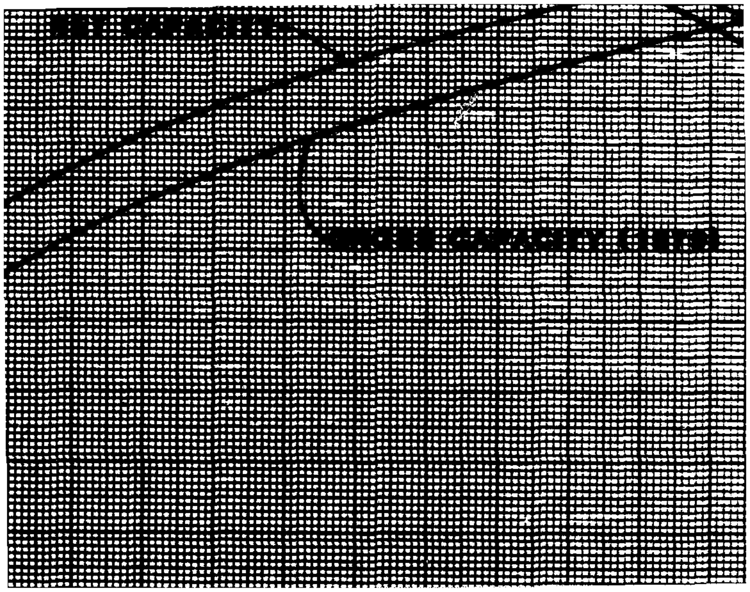
DESIGN FLOOD PEAK DISCHARGES
SANTA ANA RIVER
FUTURE CONDITIONS
WITH RECOMMENDED PLAN

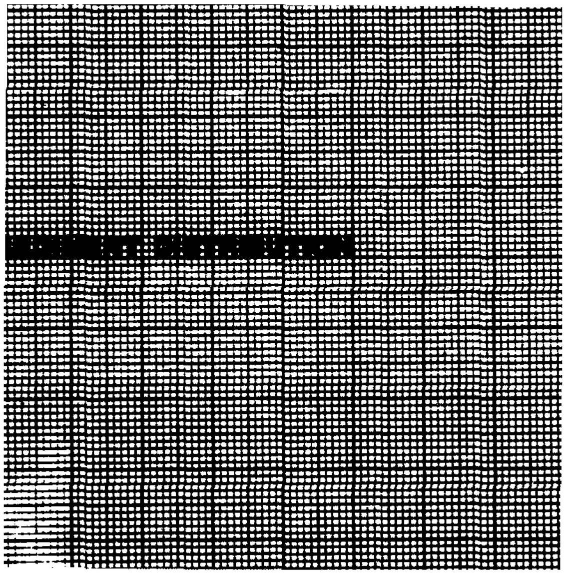
US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

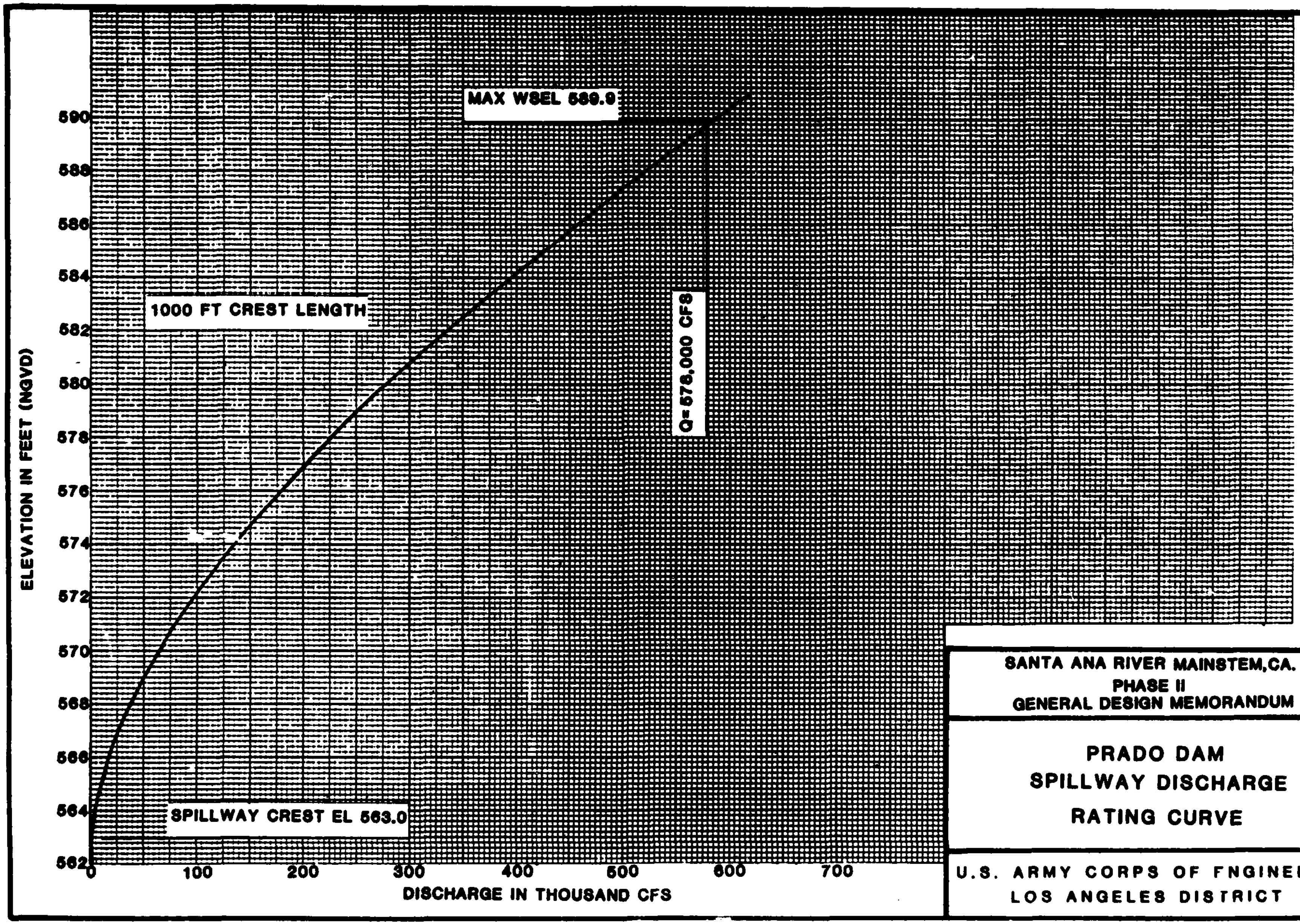
FIGURE IV-3

1

2


NET CAPACITY
GROSS CAPACITY



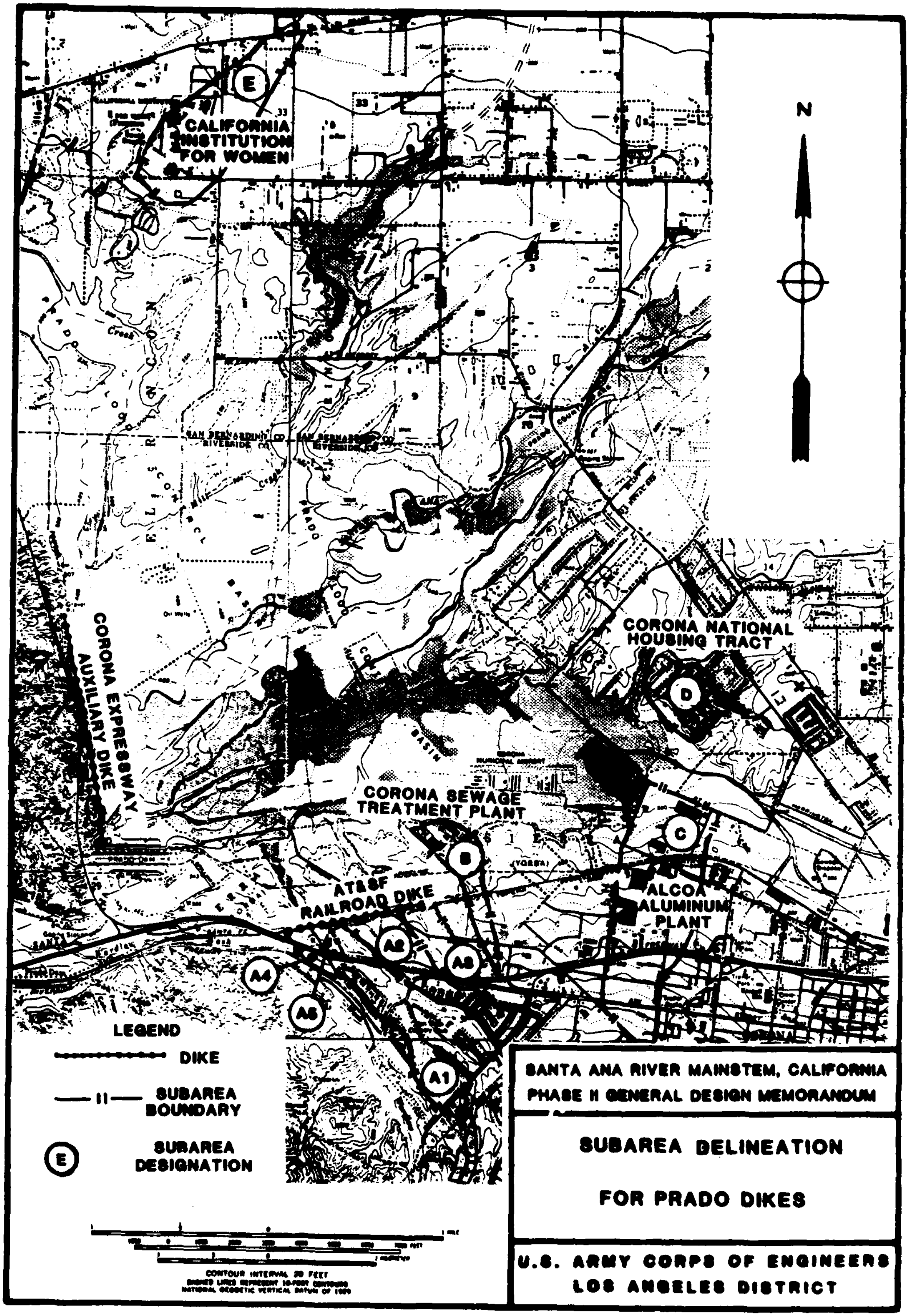


SANTA ANA RIVER MAINSTEM,CA.
PHASE II
GENERAL DESIGN MEMORANDUM

PRADO DAM
SPILLWAY DISCHARGE
RATING CURVE

U.S. ARMY CORPS OF FNGINEERS
LOS ANGELES DISTRICT

FIGURE V-2



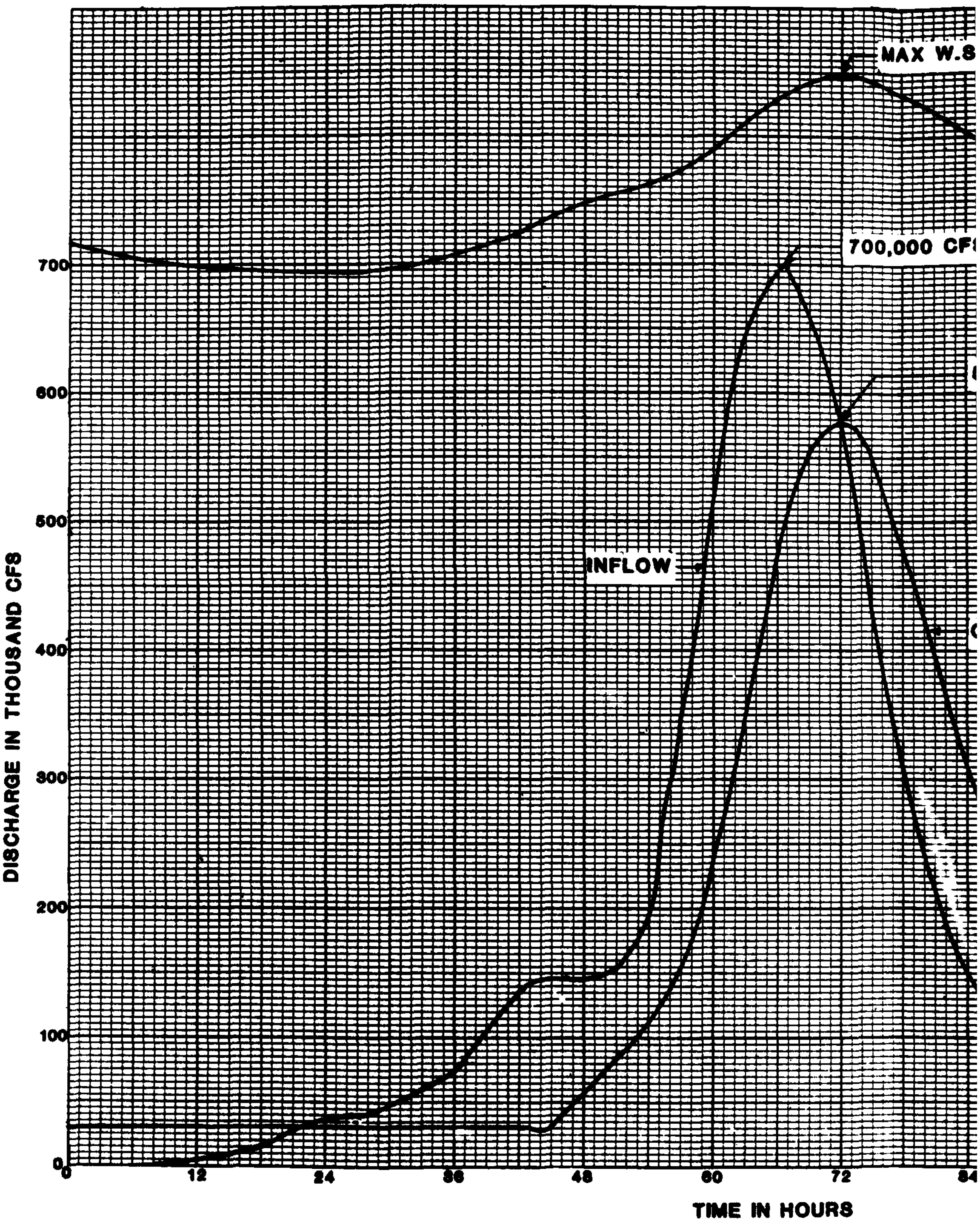
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

SUBAREA DELINEATION

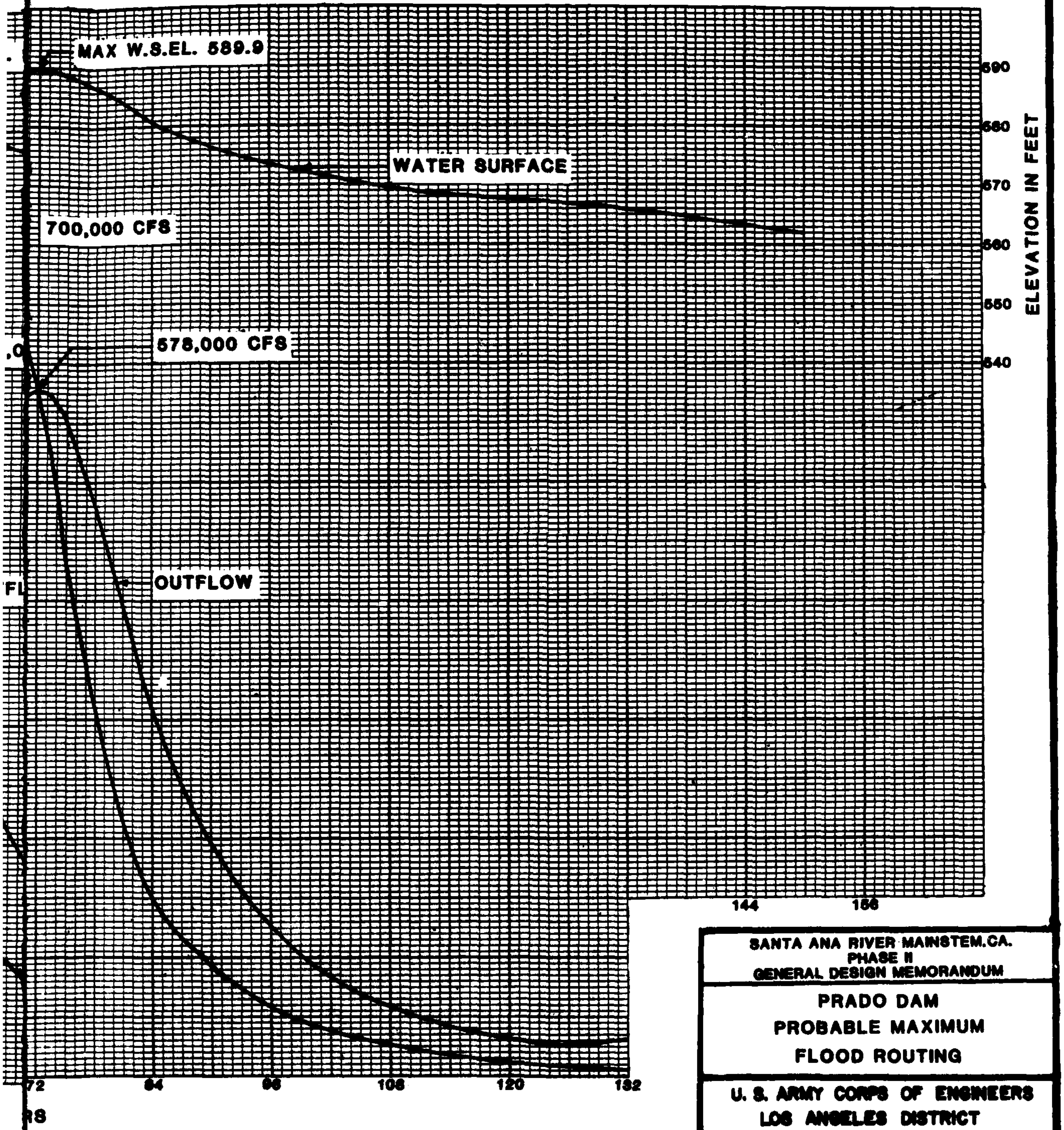
FOR PRADO DIKES

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

FIGURE V-3



VALUE ENGINEERING



SANTA ANA RIVER MAINSTEM,CA.
PHASE II
GENERAL DESIGN MEMORANDUM

PRADO DAM
PROBABLE MAXIMUM
FLOOD ROUTING

U. S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

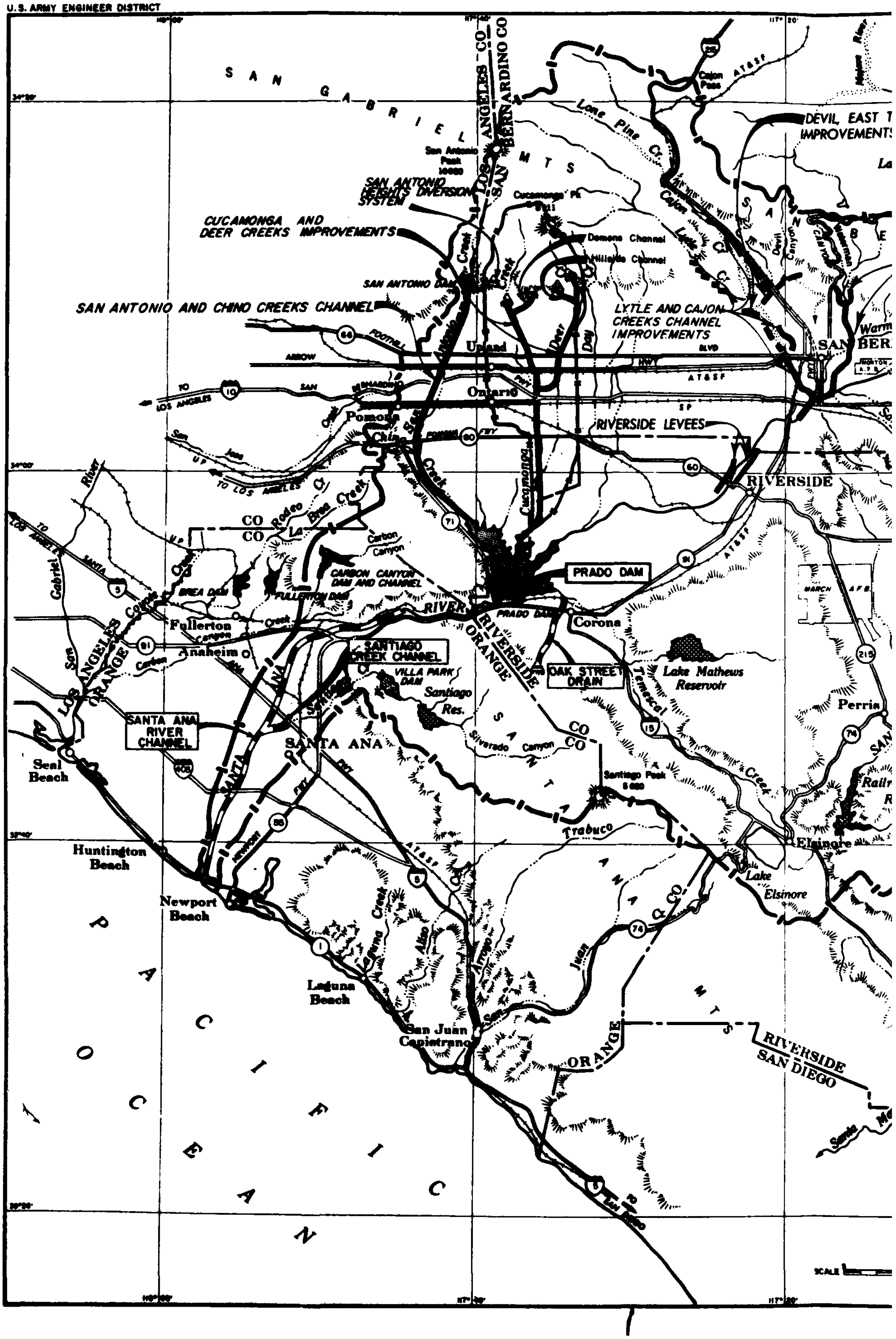
FIGURE V-4

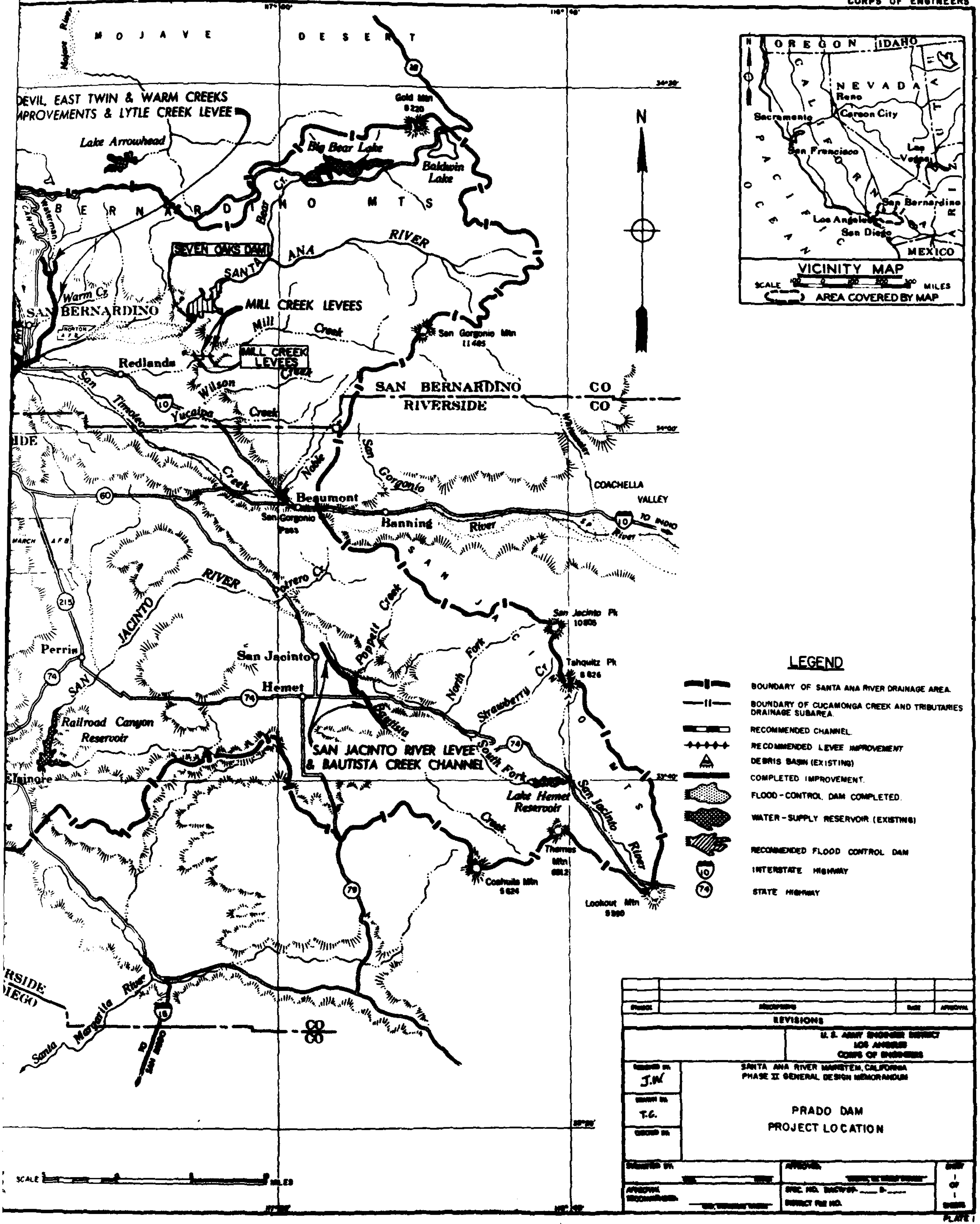
L

2

S UE ENGINEERING PAYS

U.S. ARMY ENGINEER DISTRICT





SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

DESIGNED BY: J.W.
DRAWN BY: T.G.
CHECKED BY:

PRADO DAM
PROJECT LOCATION

SUBMITTED BY:
APPROVAL:
APPROVAL RECOMMENDED:
SPEC. NO. DACW09- ___ B- ___
DISTRICT FILE NO.
SHEET 1 OF 1 SHEETS

PLATE 1

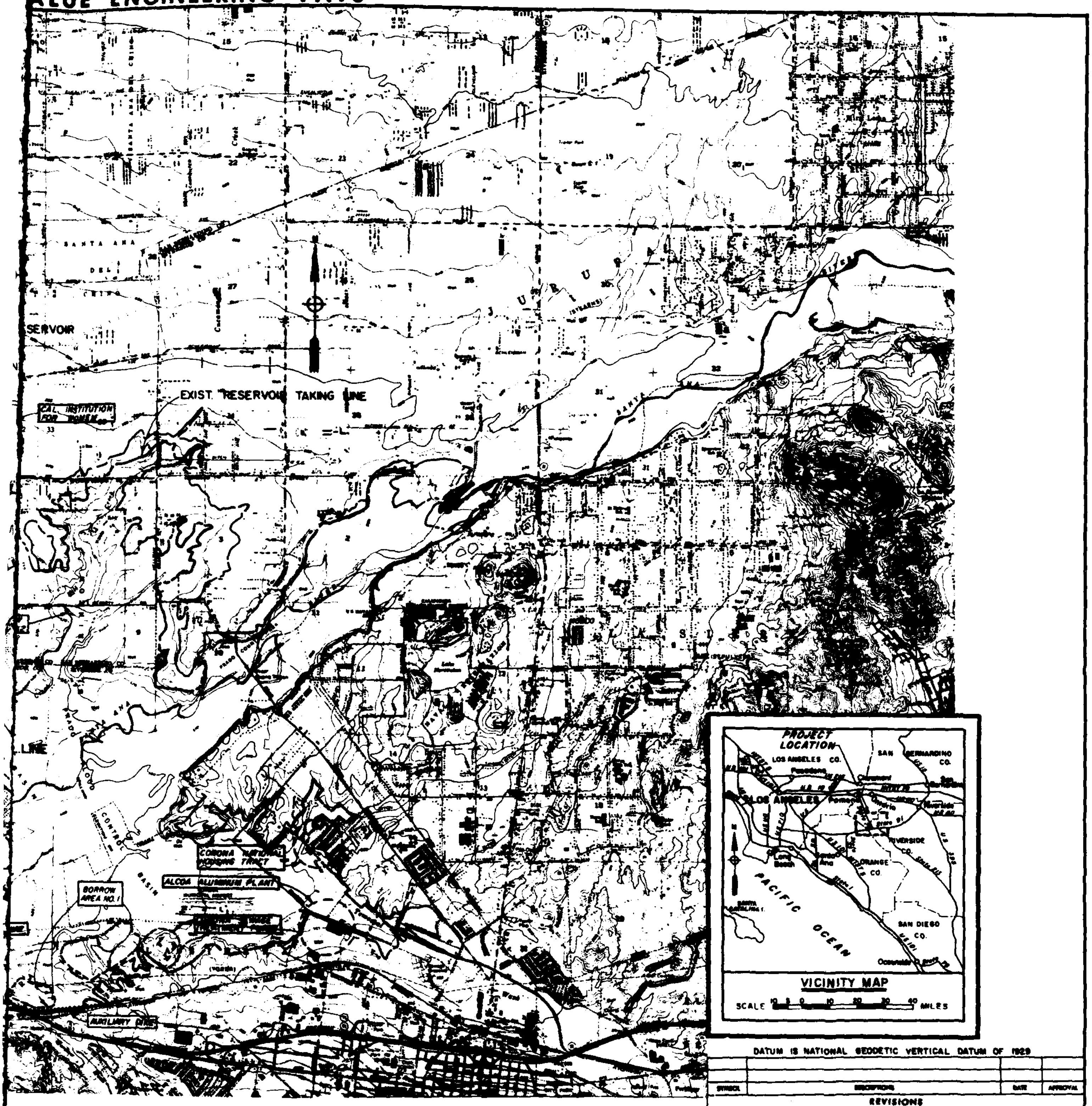
1

2

GENERAL PLAN

SCALE 2000 0 2000 4000 6000 FEET

ALUE ENGINEERING PAYS



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: J.H.A.

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
VICINITY MAP
AND RESERVOIR AREA

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET 1 OF 1

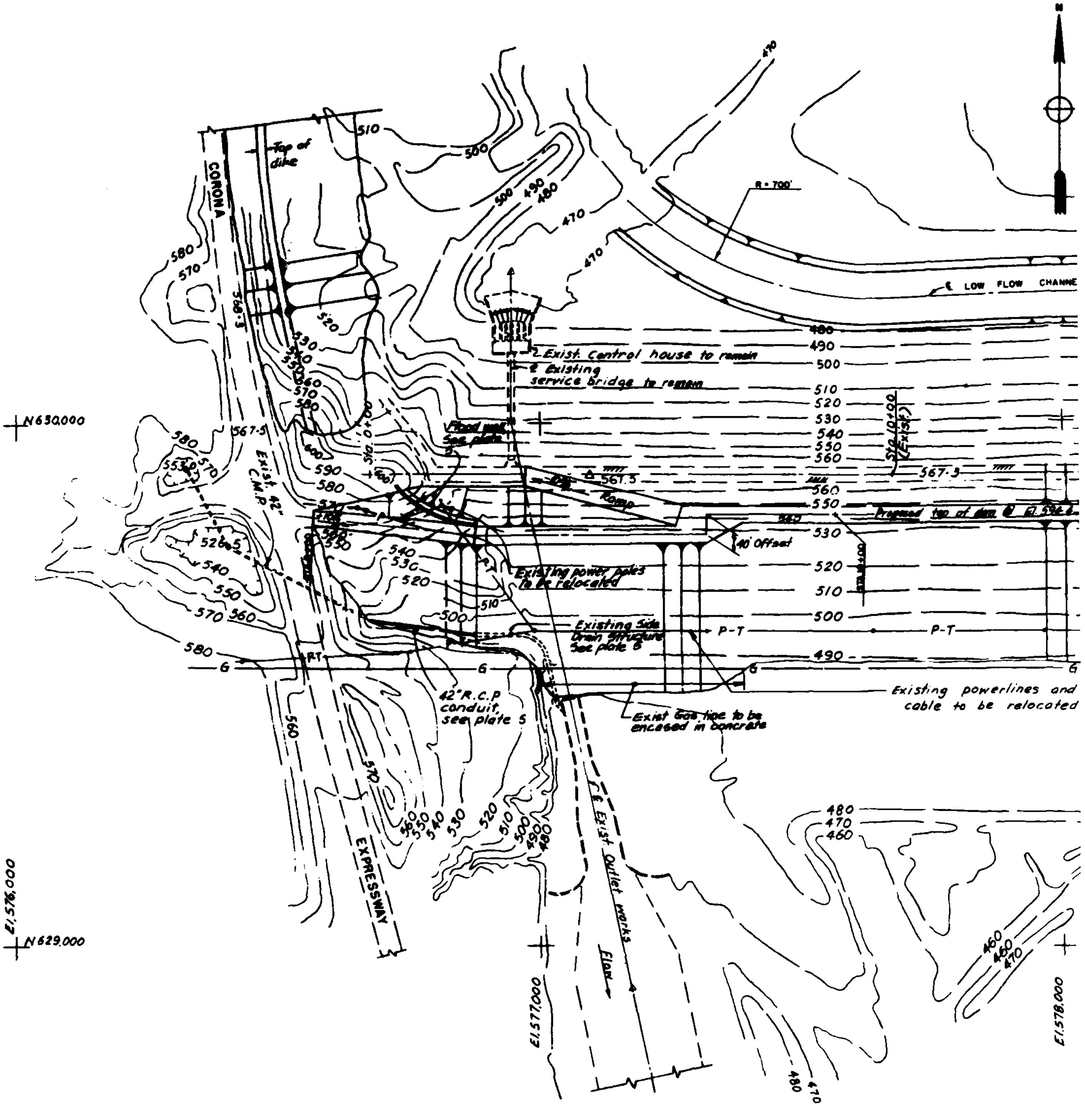
CHIEF, ________ REPORT

PLATE 2

SAFETY PAYS

2

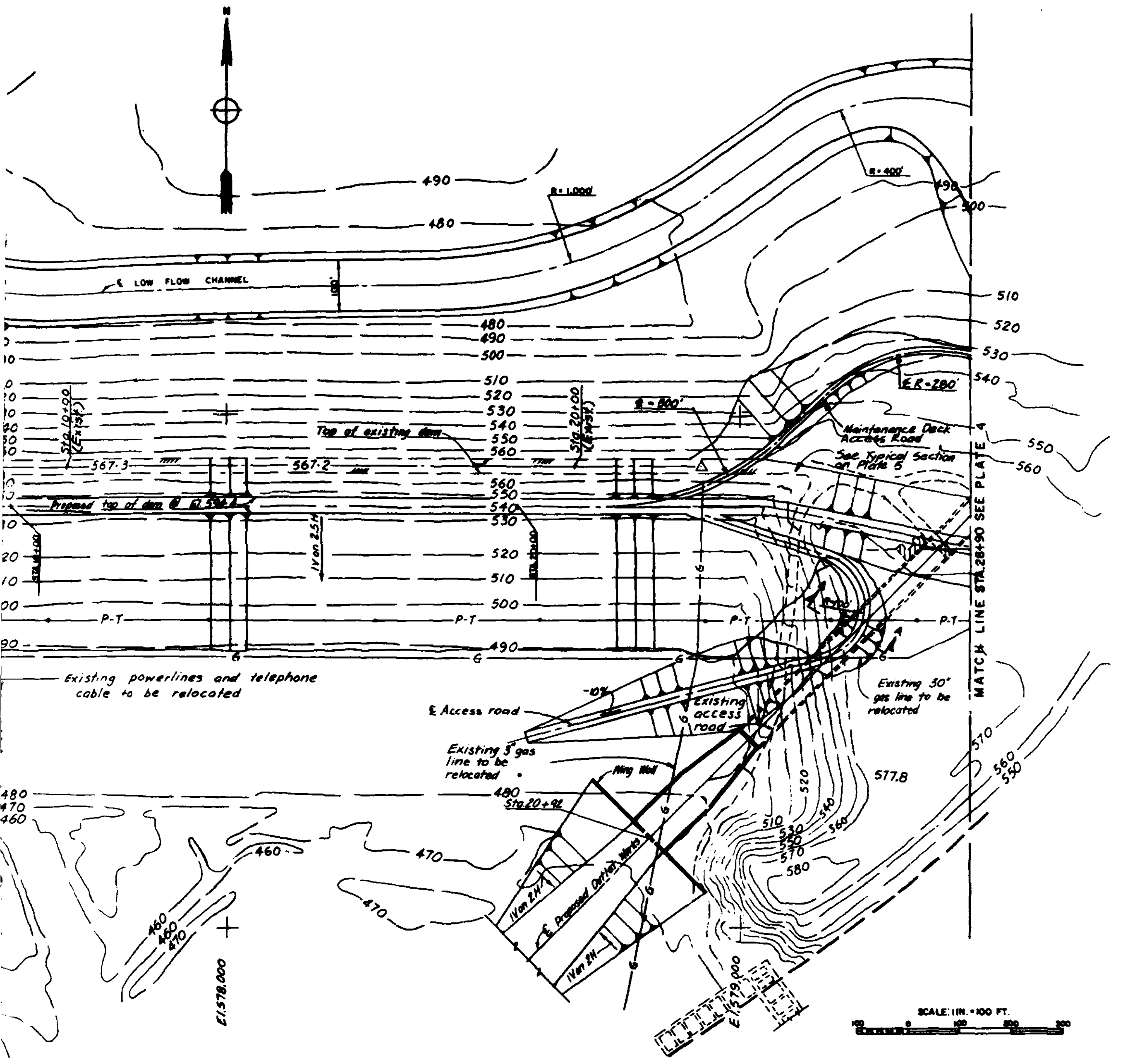
VALUE ENGINEERIN



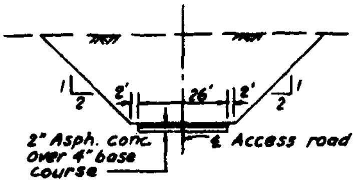
PLAN

SCALE: 1 INCH = 100 FEET

SAFETY PAY



PLAN
SCALE 1 INCH = 100 FEET



SECTION A-A
NOT TO SCALE

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

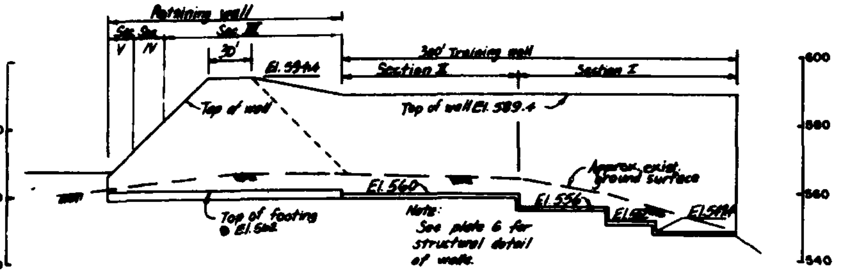
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
DAM EMBANKMENT AND SPILLWAY
PLAN AND SECTIONS

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET 1 OF 2

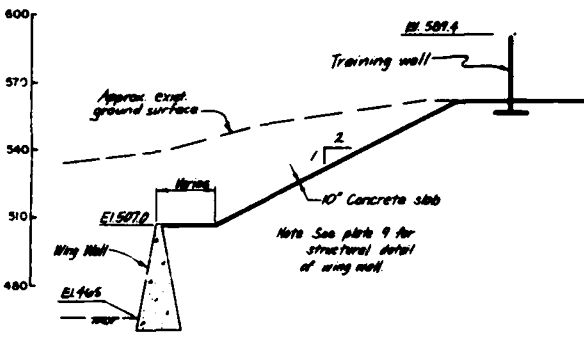
PLATE 3

2



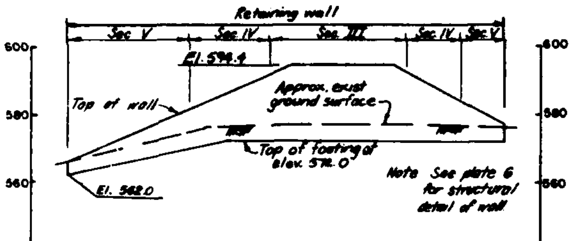
SECTION A-A

VERT. SCALE: 1 IN. = 20 FT.
HORIZ. SCALE: 1 IN. = 50 FT.



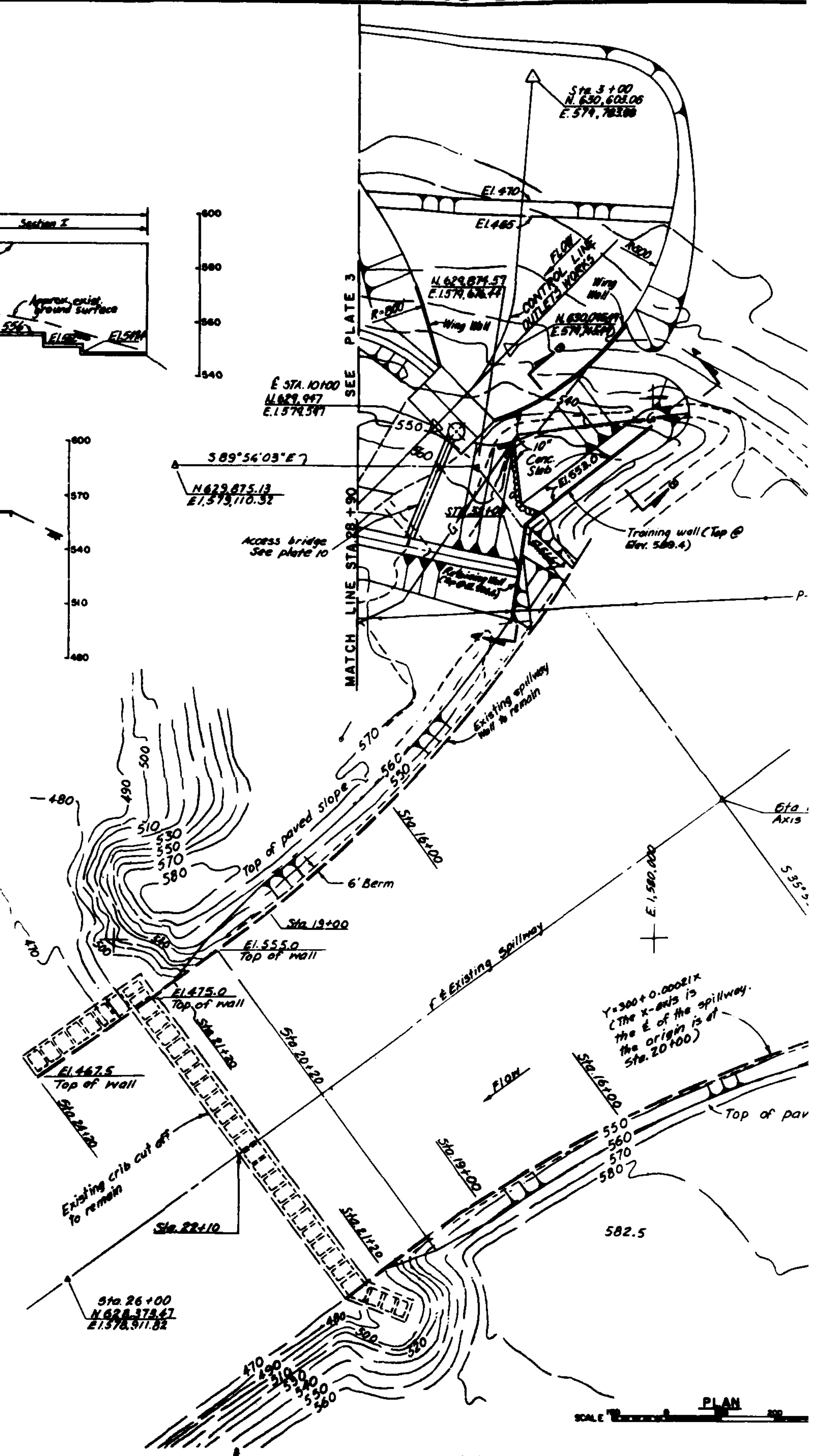
SECTION B-B

SCALE: 1 IN. = 30 FT.



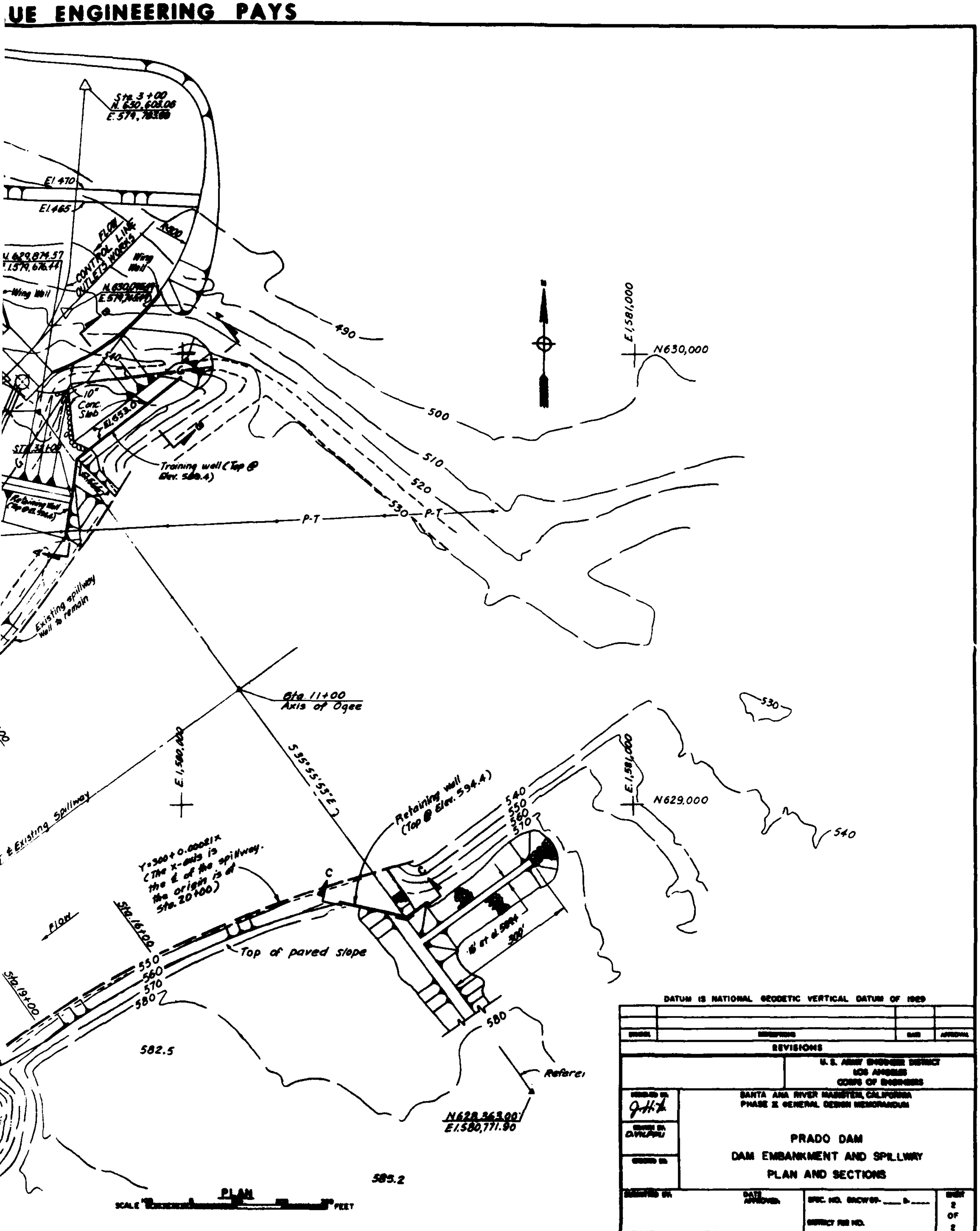
SECTION C-C

VERT. SCALE: 1 IN. = 20 FT.
HORIZ. SCALE: 1 IN. = 30 FT.



PLAN

SCALE 100 0 100 200



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

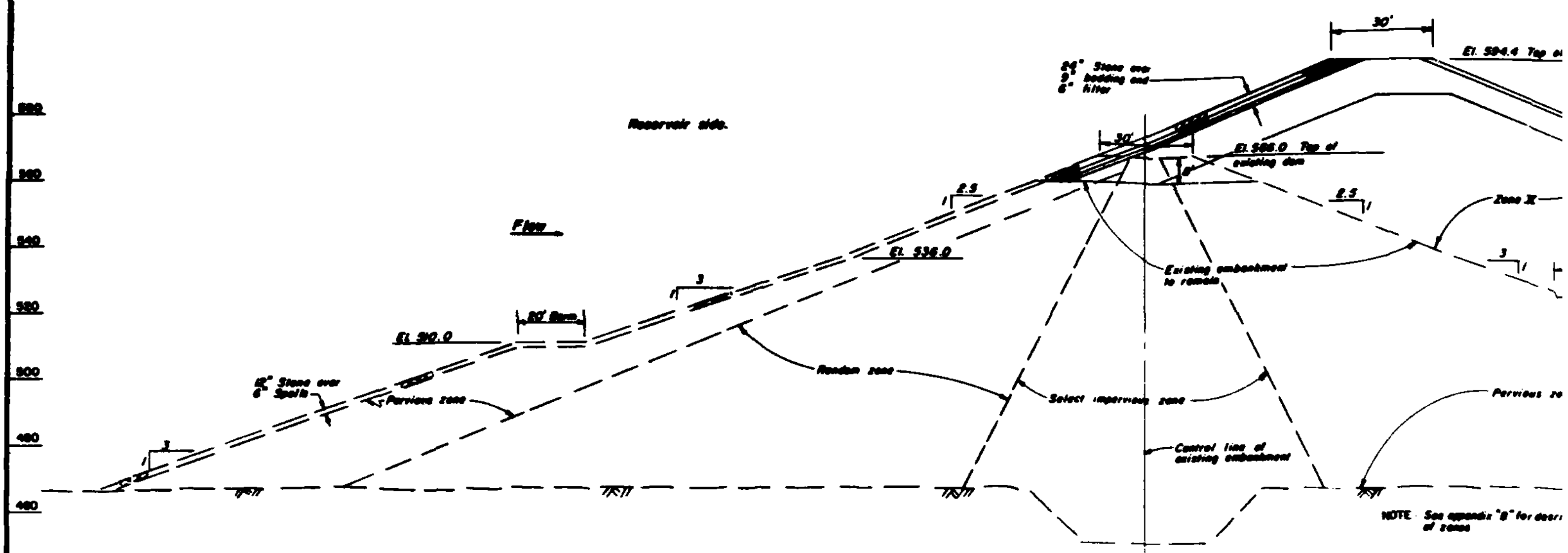
DESIGNED BY: J.H.
DRAWN BY: DVIL/PBU
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
DAM EMBANKMENT AND SPILLWAY
PLAN AND SECTIONS

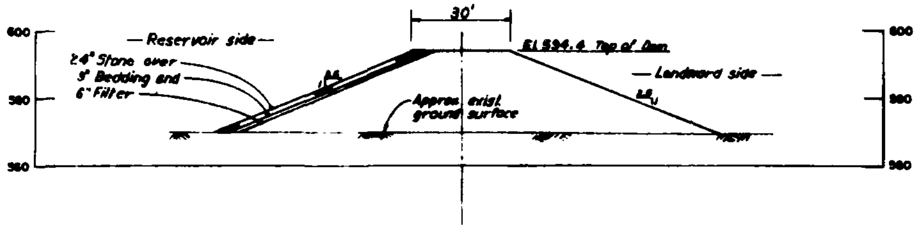
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET 2 OF 2

PLATE 4



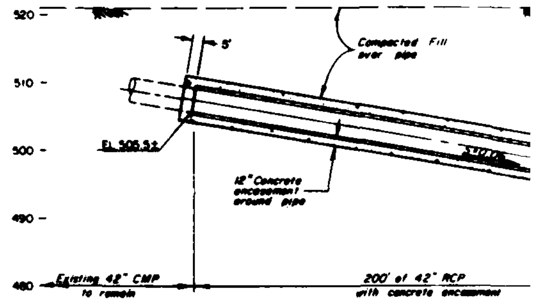
TYPICAL SECTION OF DAM BETWEEN STA. 1+20 AND STA. 24+

HORIZ SCALE: 1 IN = 20 FT
VERT SCALE: 1 IN = 20 FT

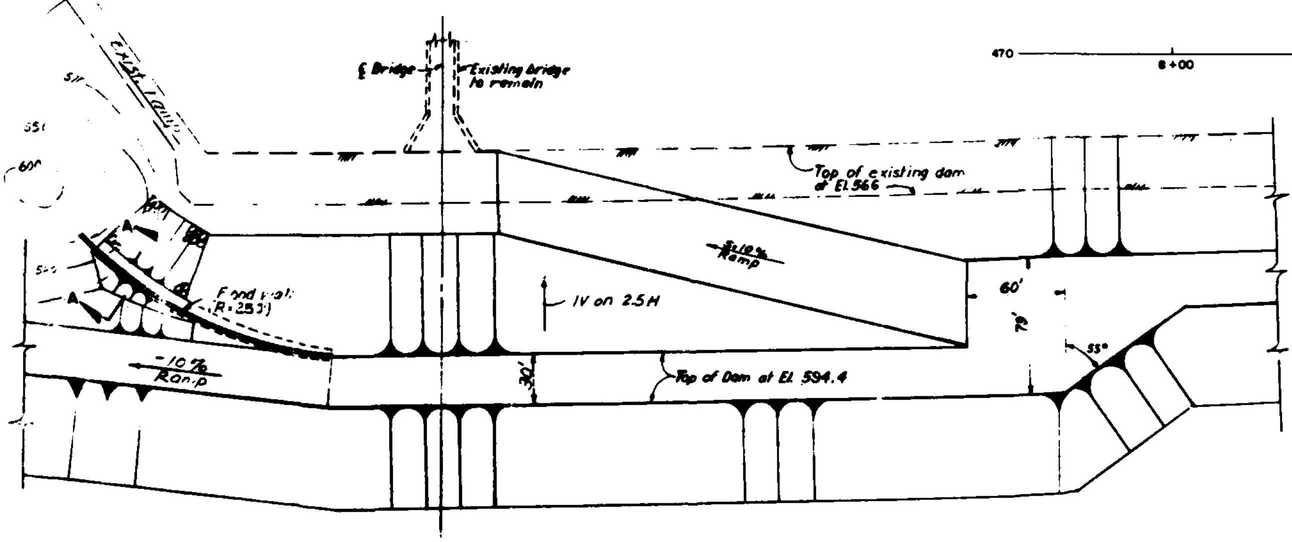


TYPICAL SECTION OF DAM BETWEEN STA. 24+30 AND 32+00

SCALE: 1 IN. = 20 FT.

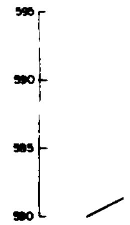


MODIFICAT

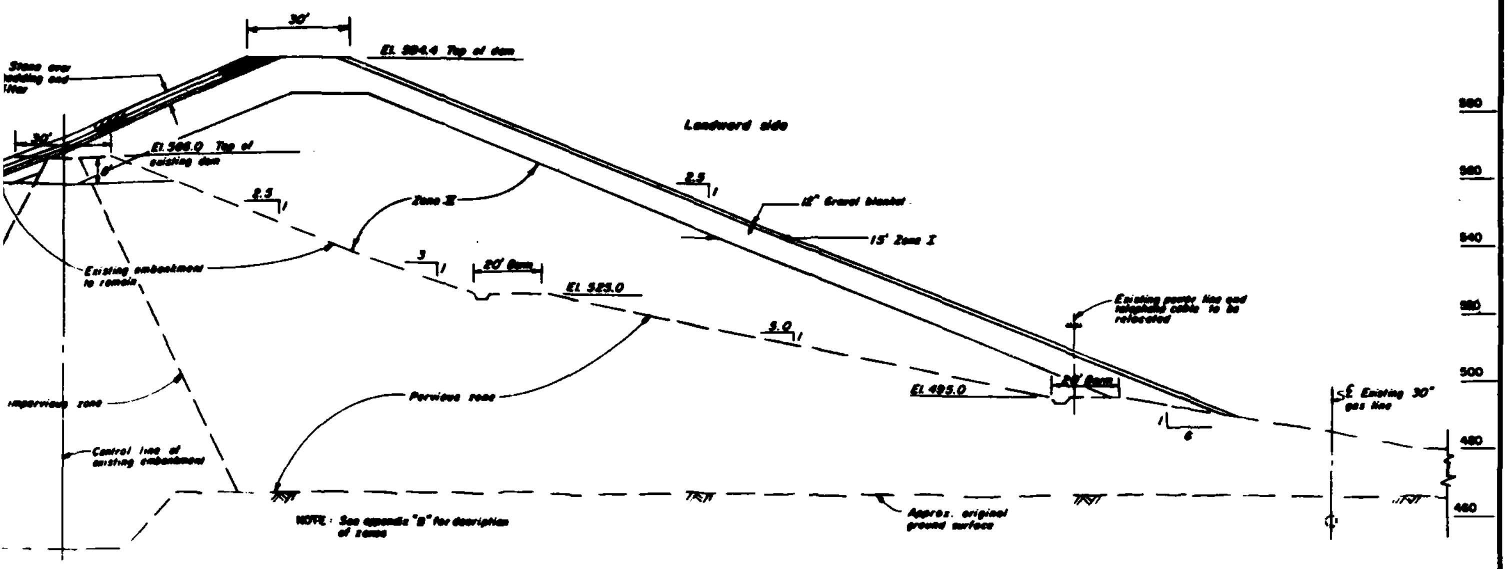


PLAN OF RIGHT EMBANKMENT

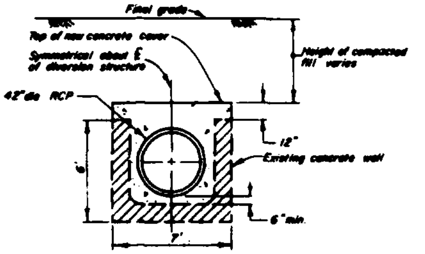
SCALE: 1 IN. = 40 FT.



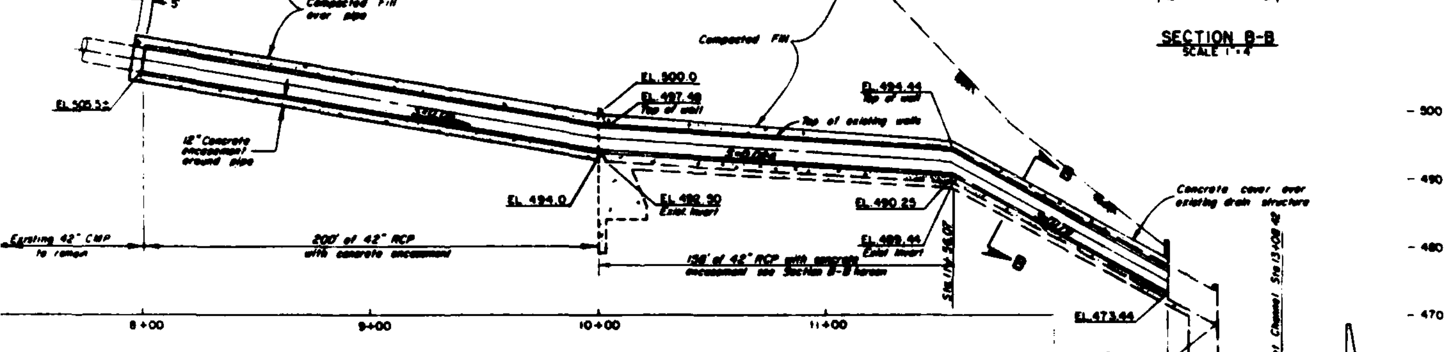
ALUE ENGINEERING PAYS



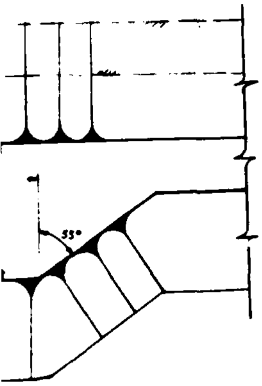
L SECTION OF DAM BETWEEN STA. 1+20 AND STA. 24+30
HORIZ SCALE: 1 IN = 20 FT
VERT SCALE: 1 IN = 20 FT

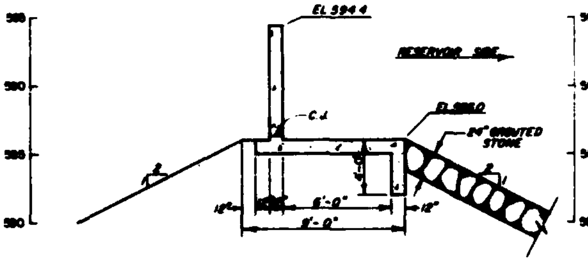


SECTION B-B
SCALE 1" = 4'

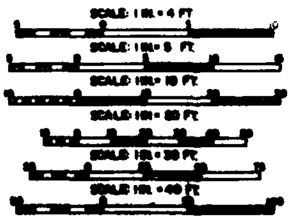


MODIFICATION OF DIVERSION STRUCTURE FOR SIDE DRAIN
HORIZ SCALE: 1 IN = 50 FT
VERT SCALE: 1 IN = 10 FT





SECTION A-A
SCALE: 1 IN = 5 FT



SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY
DRAWN BY
M.S.
CHECKED BY

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

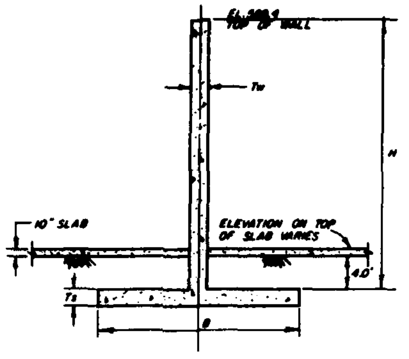
PRADO DAM
DAM EMBANKMENT
SECTIONS AND DETAILS

SUBMITTED BY
DATE APPROVED
SPEC. NO. DACW09-____-B-____
DISTRICT FILE NO.
SHEET 1 OF 1

PLATE 8

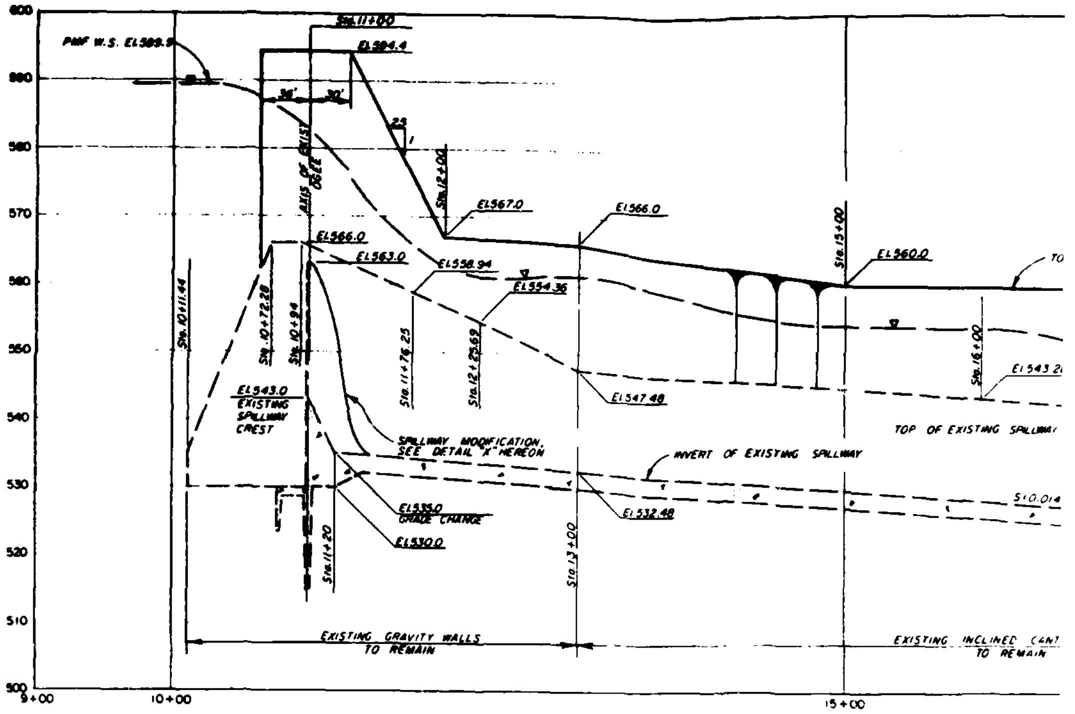
SAFETY PAYS

2



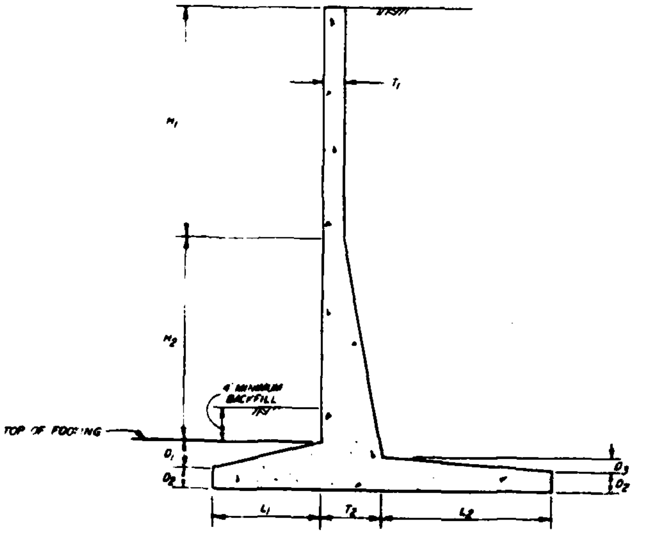
SECTION	MAX. H	B	Ts	Tw
I	40'	15'	1.25'	1.25'
II	30'	12'	1.0'	1.0'

TYPICAL TRAINING WALL SECTION
NOT TO SCALE



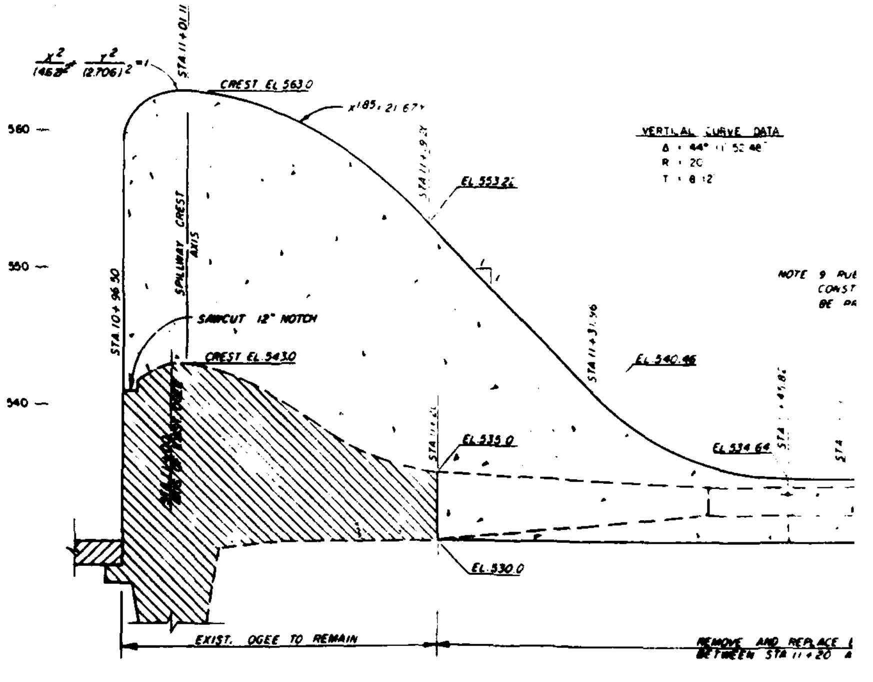
PROFILE

HORIZ SCALE 50 0 50 100 150 FEET
VERT SCALE 10 0 10 20 30 FEET

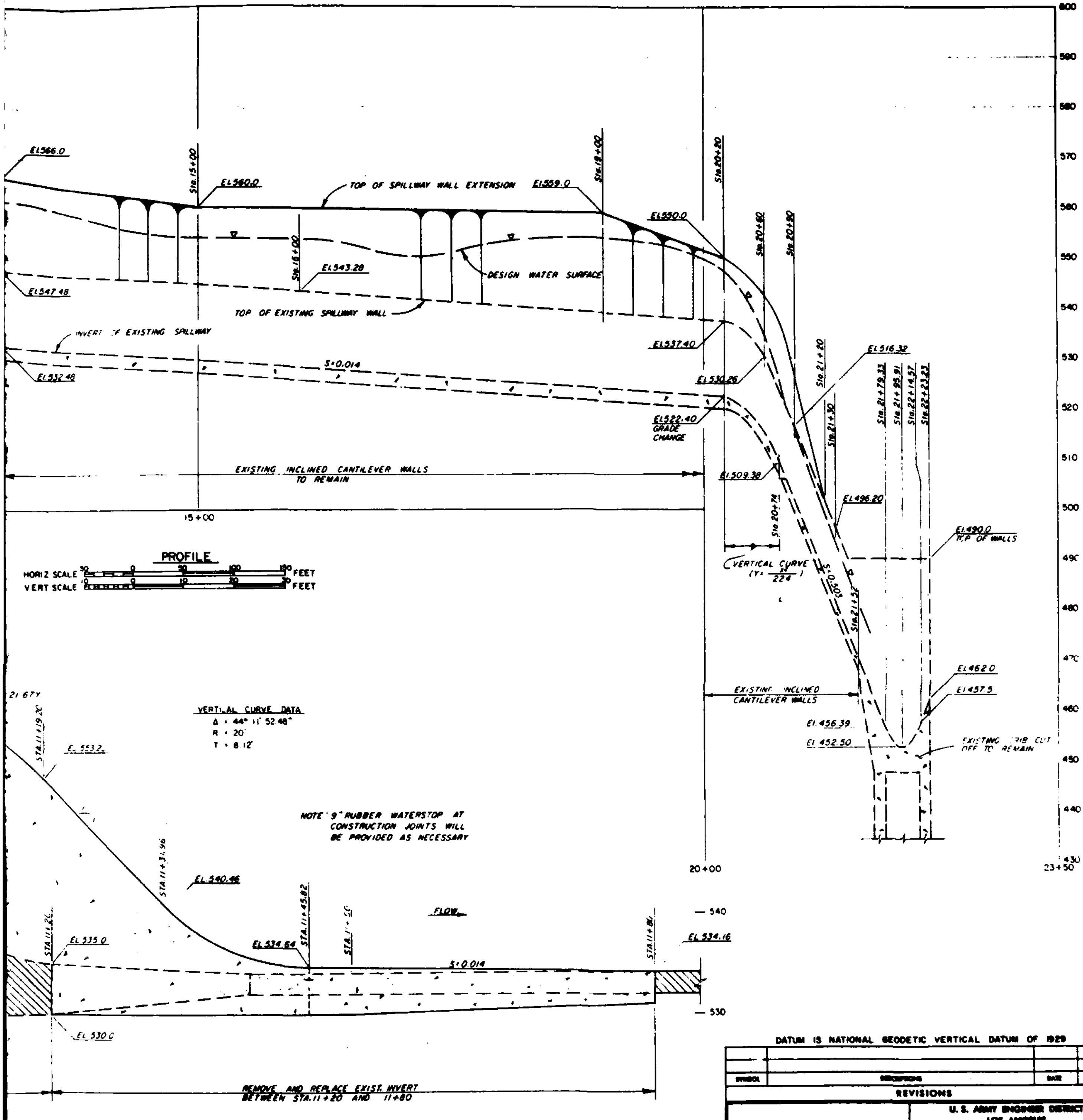


SECTION	H1	H2	D1	D2	D3	L1	L2	T1	T2
III	17' to 7"	14'-10"	2'-0"	1'-6"	10"	8'-3"	12'-6"	1'-6"	4'-0"
IV	12' to 4'	8'-0"	0'-6"	12"	0'-6"	3'-0"	7'-6"	12"	1'-6"
V	12' to 0'	0	0	12"	0	2'-0"	5'-6"	12"	12"

TYPICAL RETAINING WALL SECTION
NOT TO SCALE



DETAIL "X"
SCALE 1 IN = 5 FT



PROFILE

VERTICAL CURVE DATA
Δ = 44° 11' 52.48"
R = 20'
T = 8.12'

NOTE: 9" RUBBER WATERSTOP AT CONSTRUCTION JOINTS WILL BE PROVIDED AS NECESSARY

DETAIL "X"
SCALE 1 IN. = 5 FT.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
SPILLWAY
PROFILE, DETAIL AND SECTIONS

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

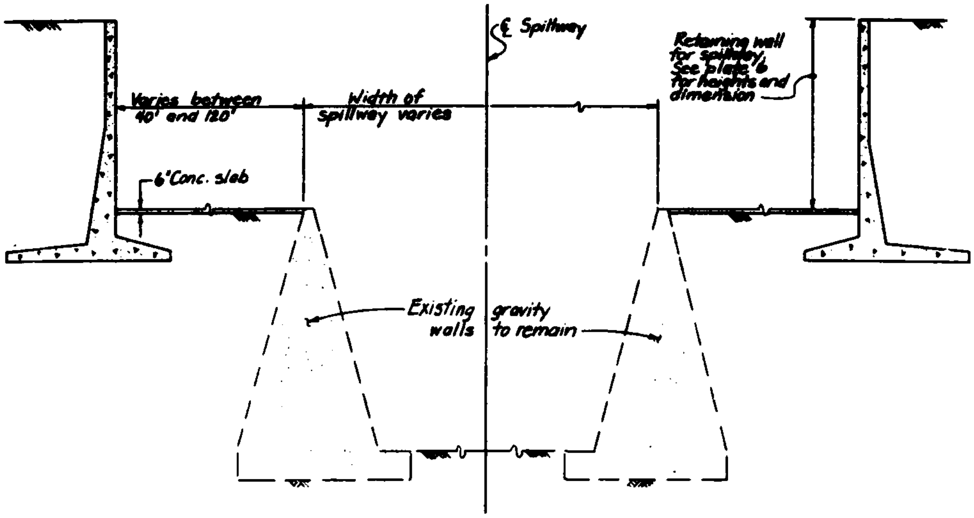
DISTRICT FILE NO.

SHEET 1 OF 1 SHEET

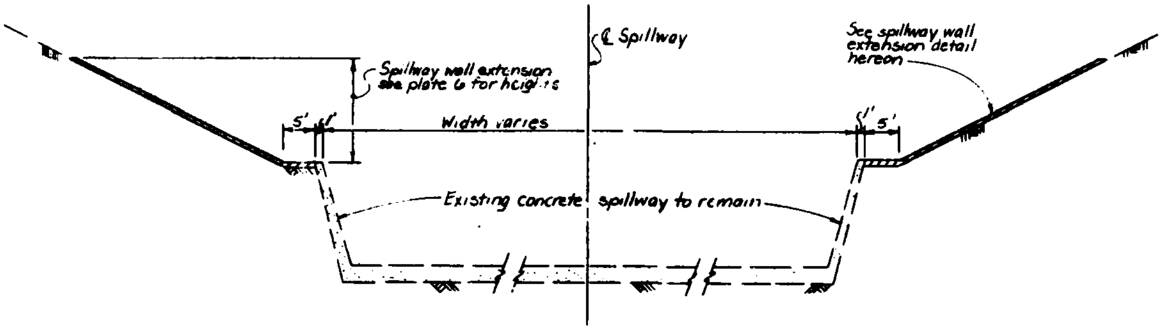
PLATE 6

SAFETY PAYS

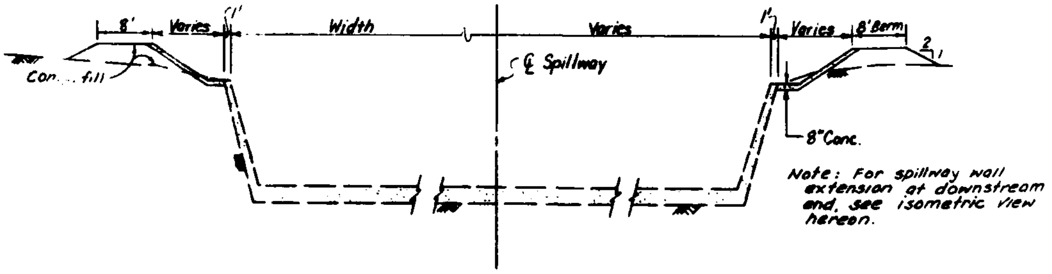
VALUE ENGINEERING P



STA.10+64 TO STA. 12+00



STA.12+00 TO STA.20+20

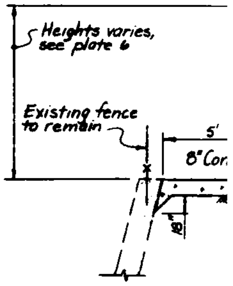


Note: For spillway wall extension at downstream end, see isometric view hereon.

STA.20+20 TO STA.21+20

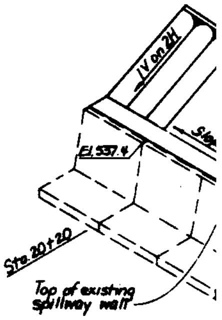
TYPICAL SPILLWAY SECTIONS

SCALE: 1 IN. = 10 FT.



SPILLWAY-WALL-

NOT T



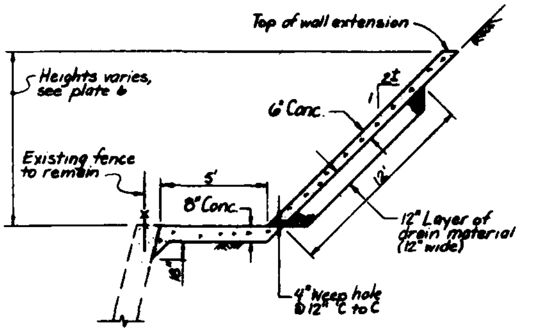
ISOME

WALL EXTENSI

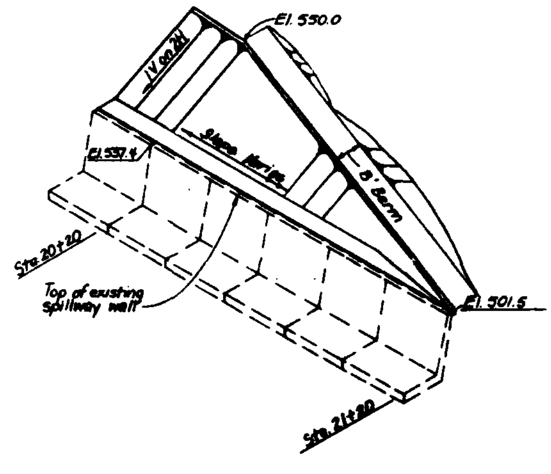
SCAL

SAFETY PAYS

S UE ENGINEERING PAYS



SPILLWAY-WALL-EXTENSION DETAIL
NOT TO SCALE



ISOMETRIC VIEW OF
WALL EXTENSION AT DOWNSTREAM END
SCALE: 1 IN. = 50 FT.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
SPILLWAY
SECTIONS AND DETAILS

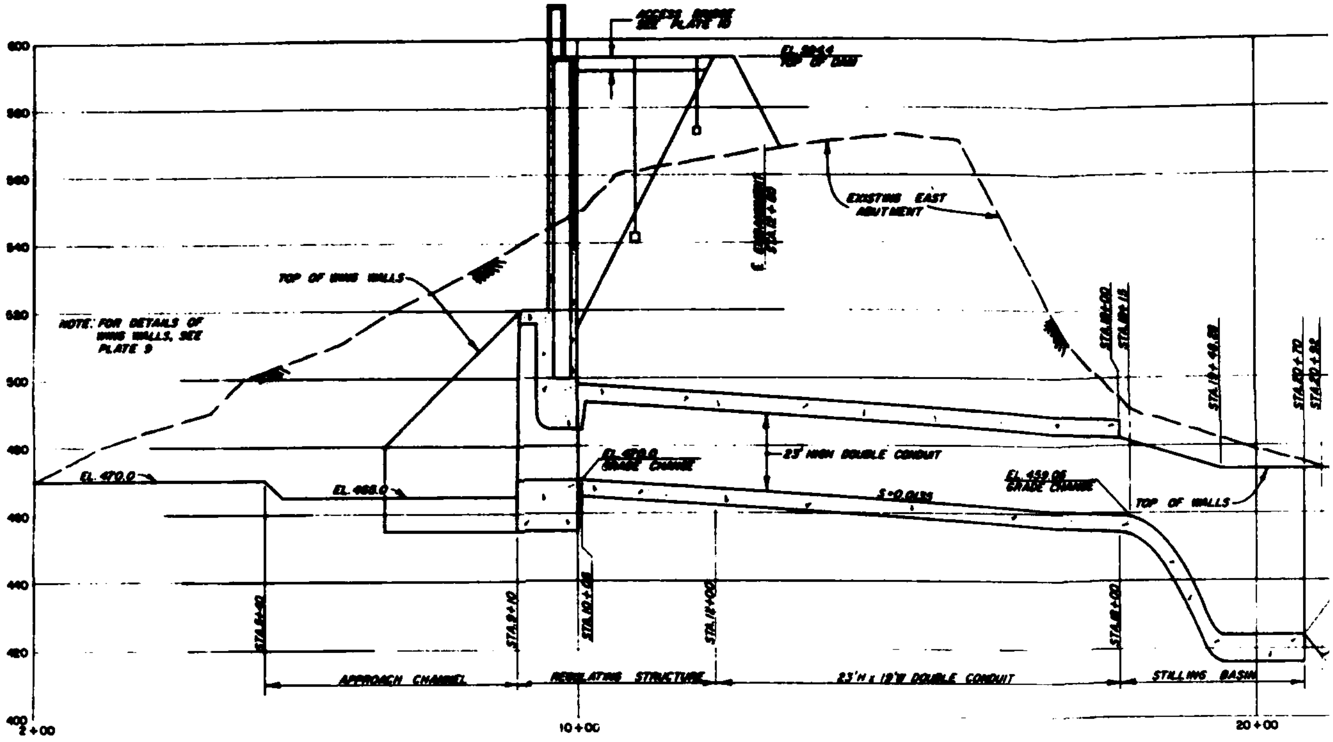
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET 1 OF 1

PLATE 7

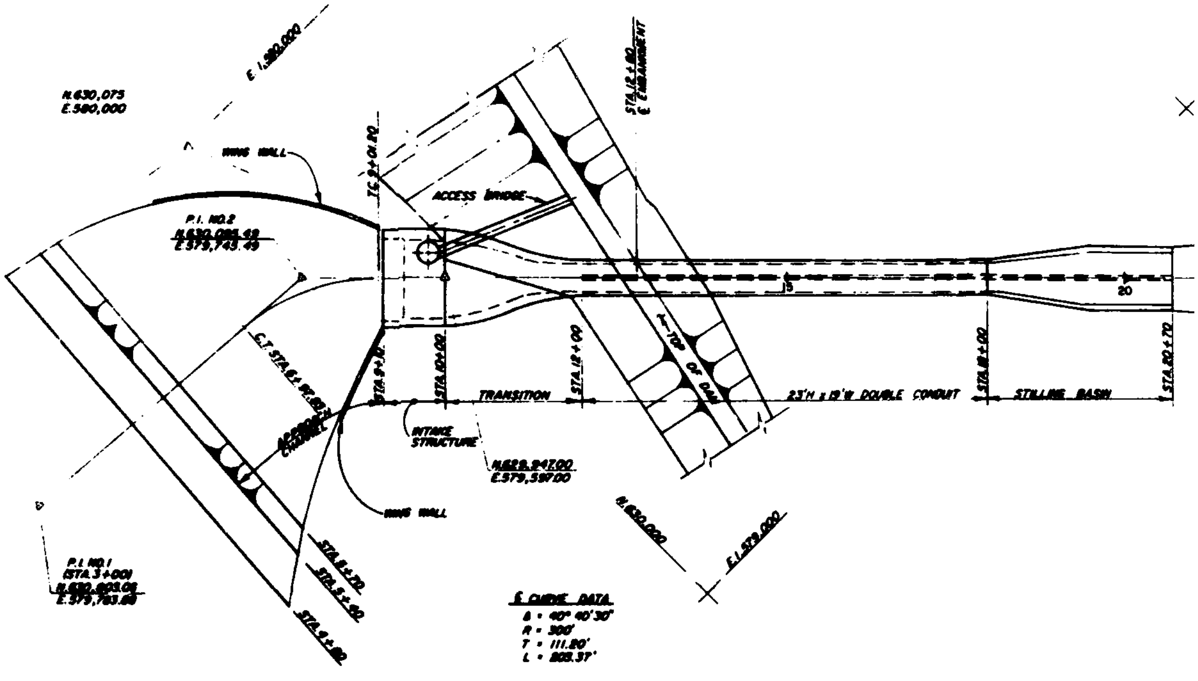
SAFETY PAYS

2

VALUE ENGINEERIN

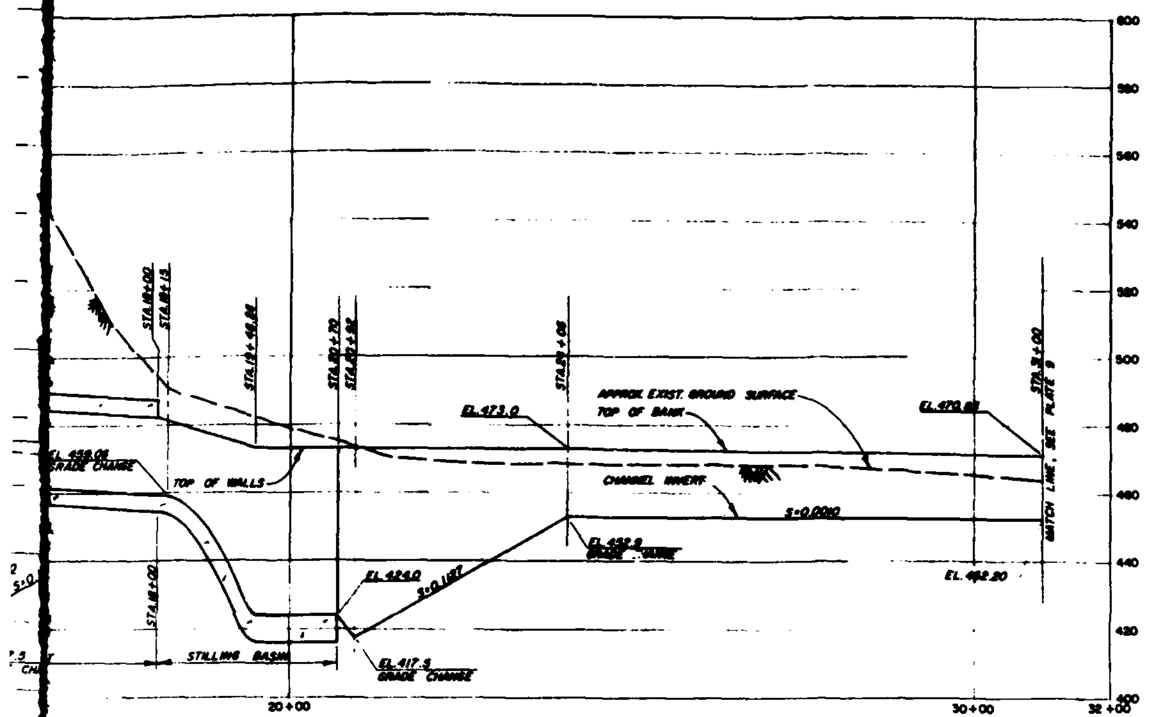


PROFILE
HORIZ. SCALE: 1 IN. = 100 FT.
VERT. SCALE: 1 IN. = 20 FT.

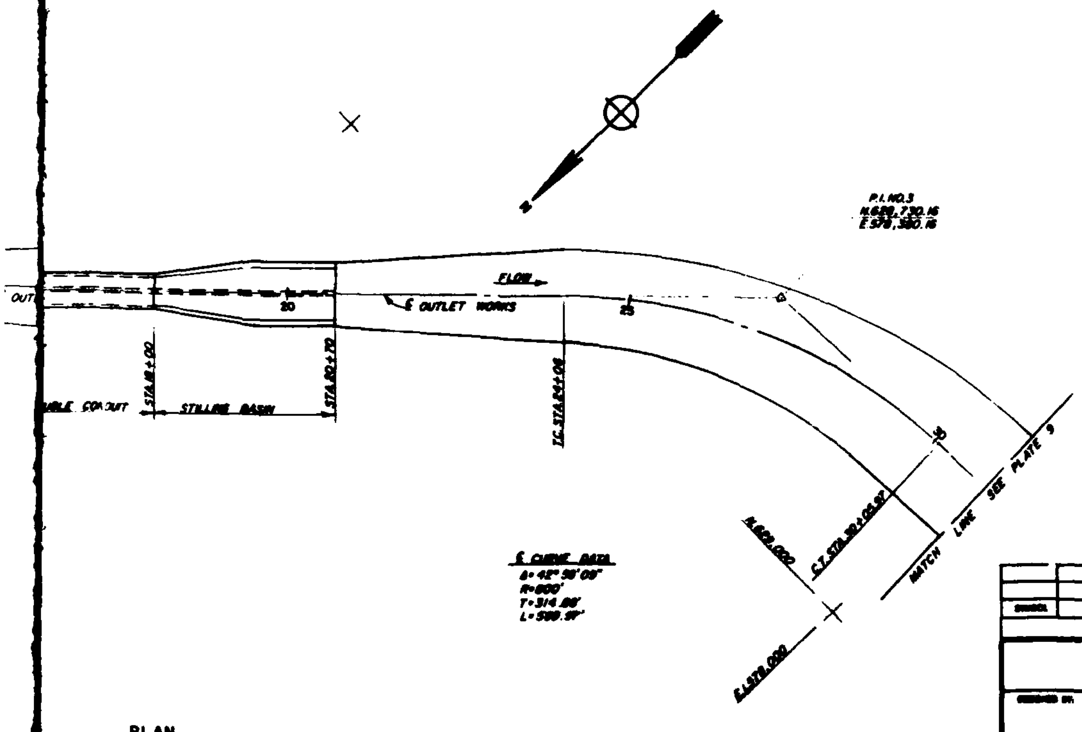


PLAN
1 IN. = 100 FT

SAFETY PAY



PROFILE
HORIZ. SCALE 1 IN. = 100 FT.
VERT. SCALE 1 IN. = 20 FT.



PLAN
1 IN. = 100 FT.

SCALE: 1 IN. = 20 FT.
10 0 10 20 30 40 50

SCALE: 1 IN. = 100 FT.
100 0 100 200 300

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:
D.Castro

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
PLAN AND PROFILE

SUBMITTED BY:

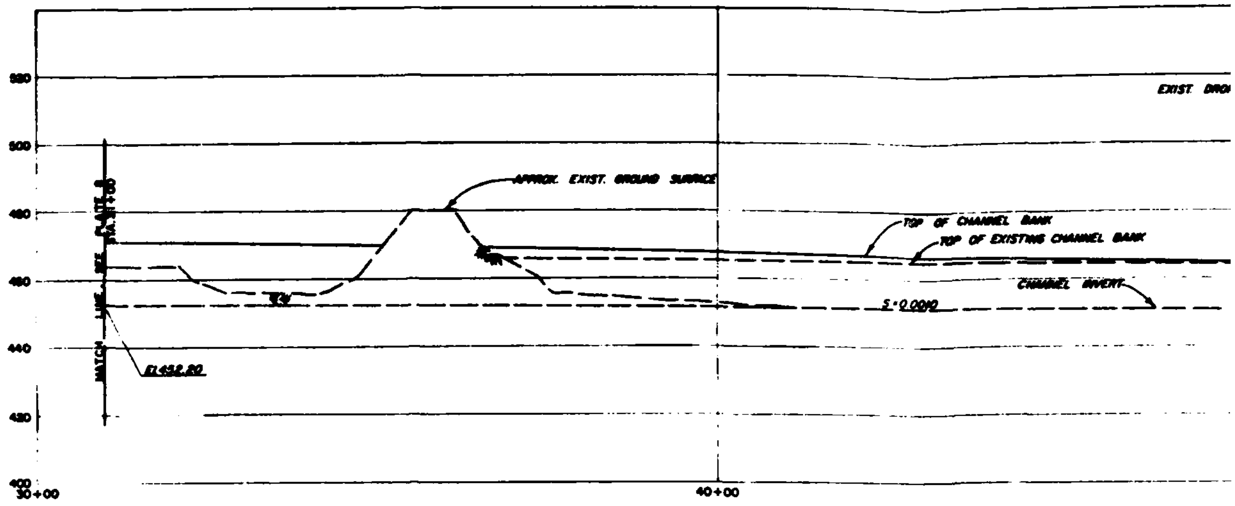
DATE APPROVED:

SPEC. NO. DACW09-____ B-____

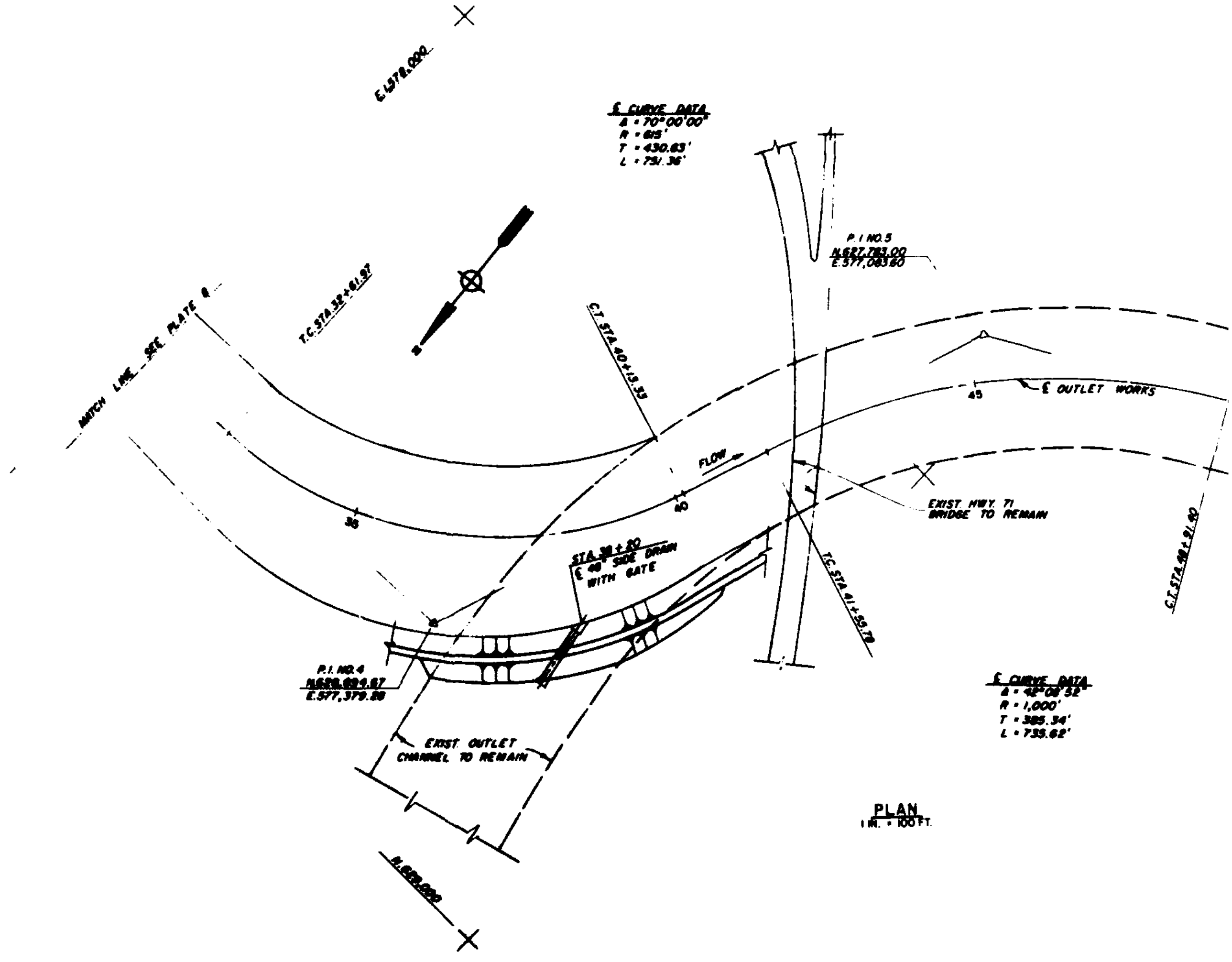
DISTRICT FILE NO.

SHEET 1 OF 2

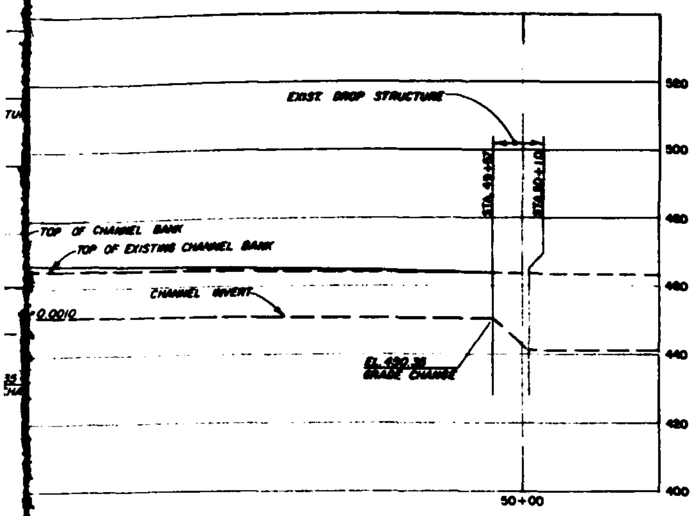
PLATE 8

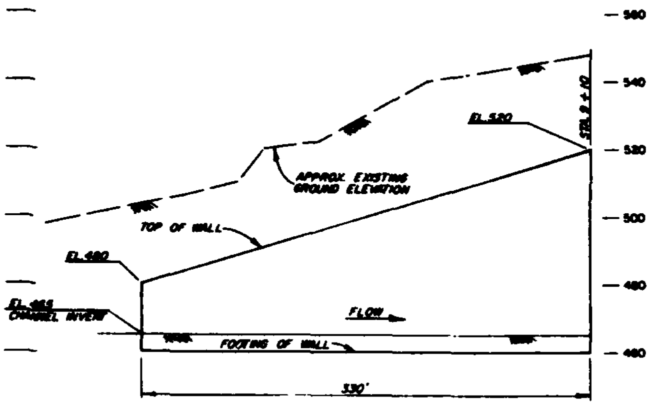


PROFILE
HORIZ. SCALE: 1 IN. = 100 FT.
VERT. SCALE: 1 IN. = 20 FT.

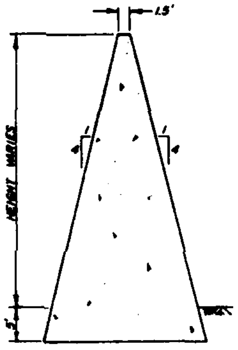


PLAN
1 IN. = 100 FT.

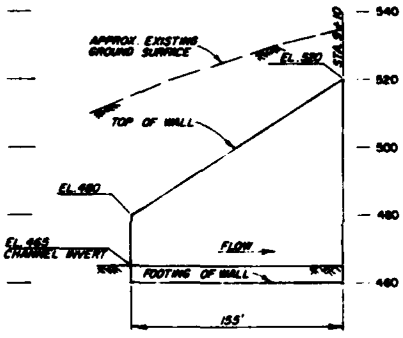




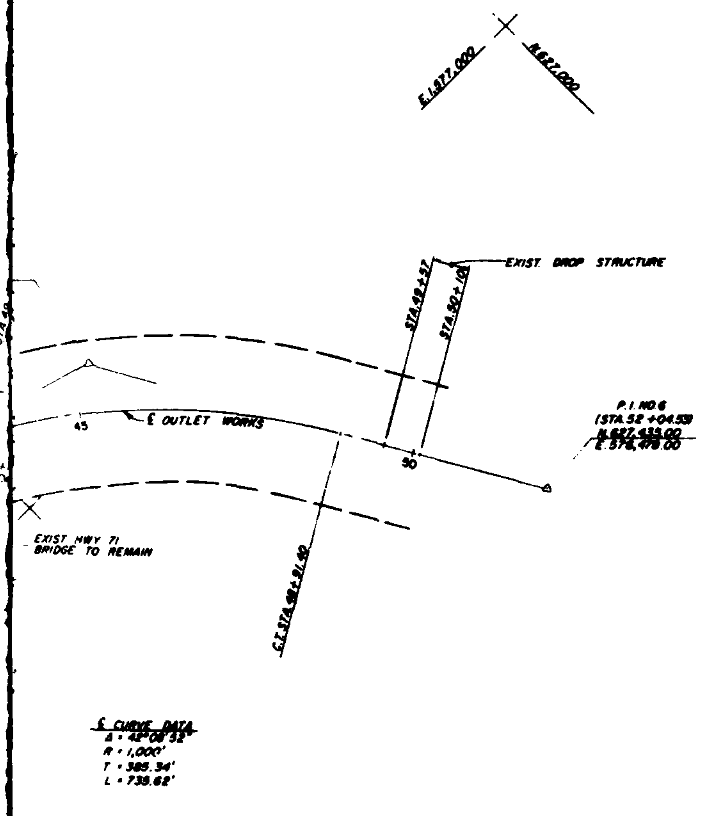
PROFILE OF EAST WINGWALL
HORIZ. SCALE: 1 IN. = 50 FT.
VERT. SCALE: 1 IN. = 20 FT.

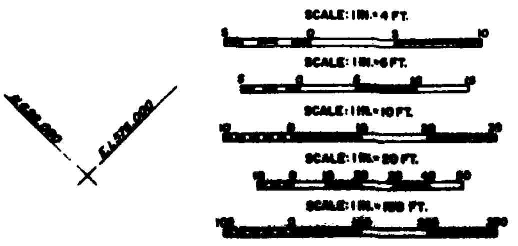


TYPICAL WINGWALL SECTION
1 IN. = 10 FT.



PROFILE OF WEST WINGWALL
HORIZ. SCALE: 1 IN. = 50 FT.
VERT. SCALE: 1 IN. = 20 FT.





SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY: D. Cinofre

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
PLAN AND PROFILE

SUBMITTED BY:

DATE APPROVED:

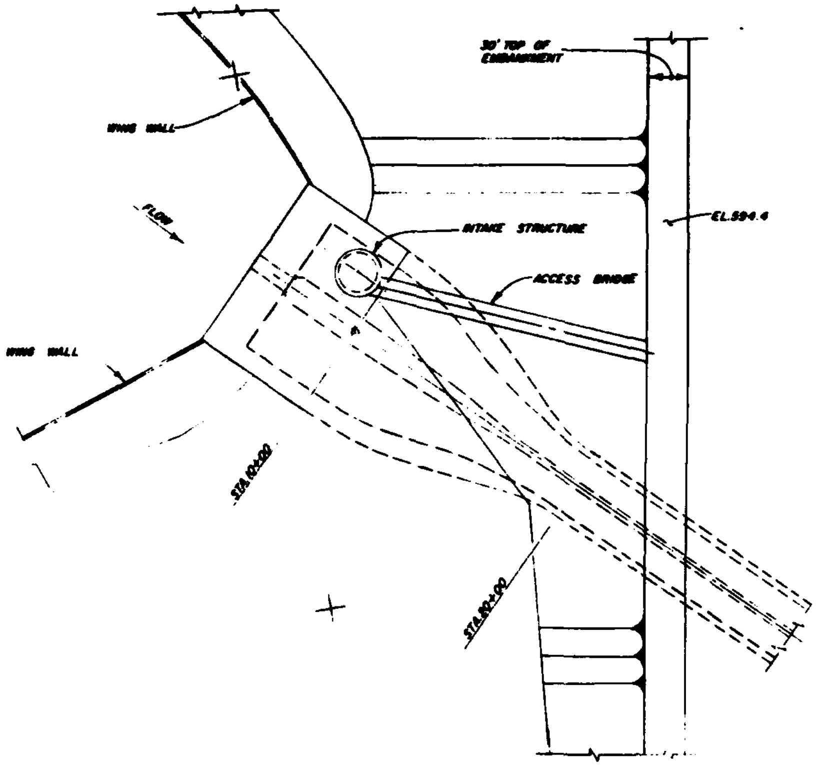
SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

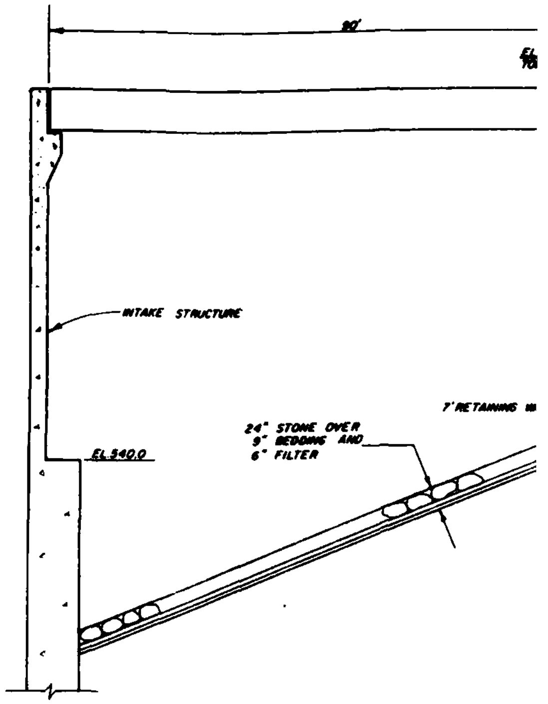
SHEET 2 OF 2 SHEETS

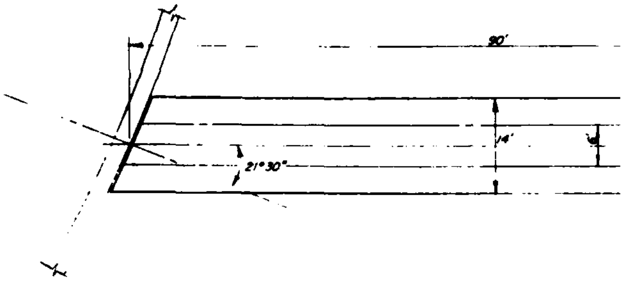
PLATE 9

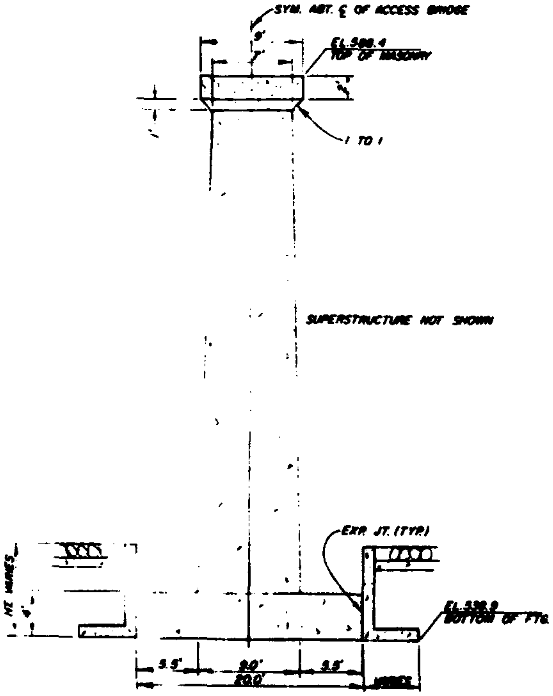
2



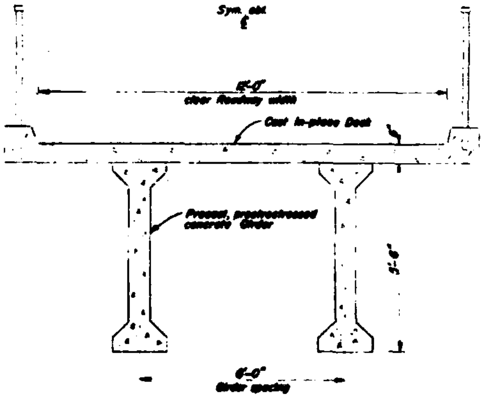
PLAN
1 IN. = 50 FT.





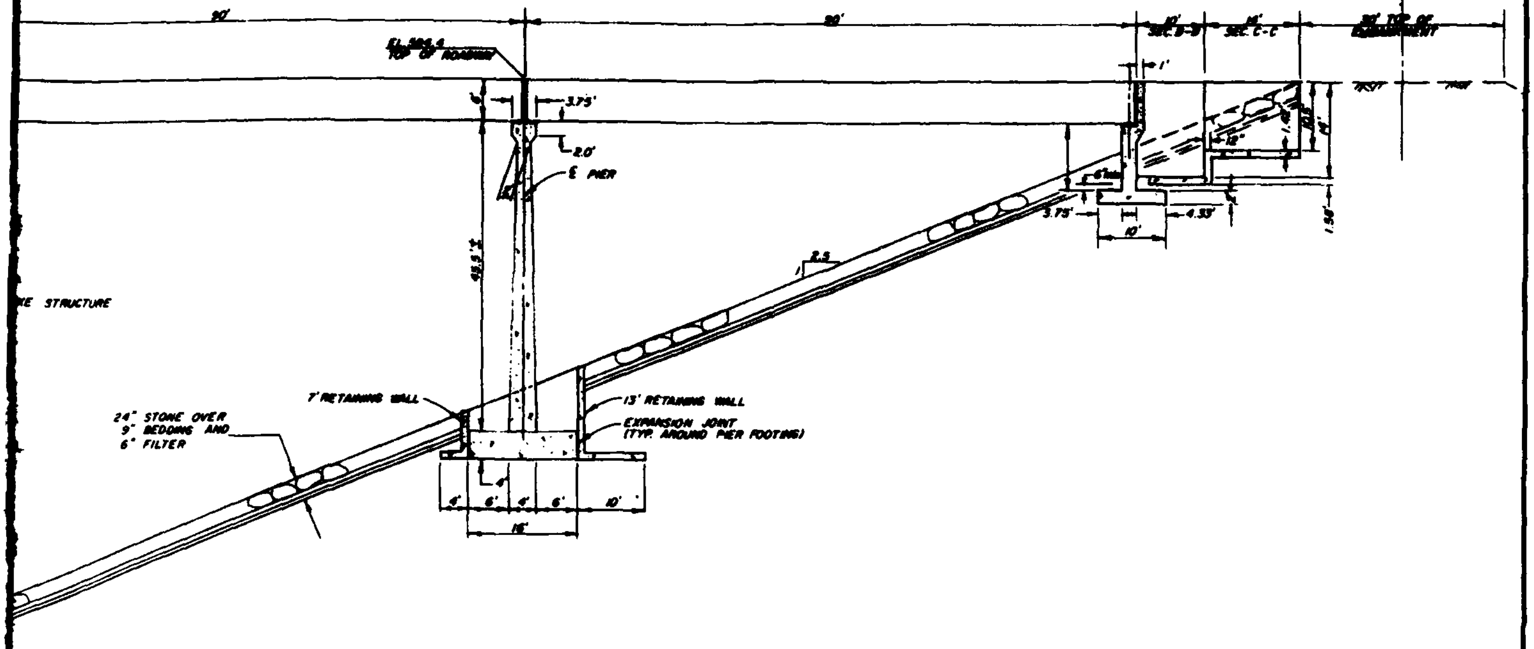


PIER ELEVATION
1 IN. = 6 FT.

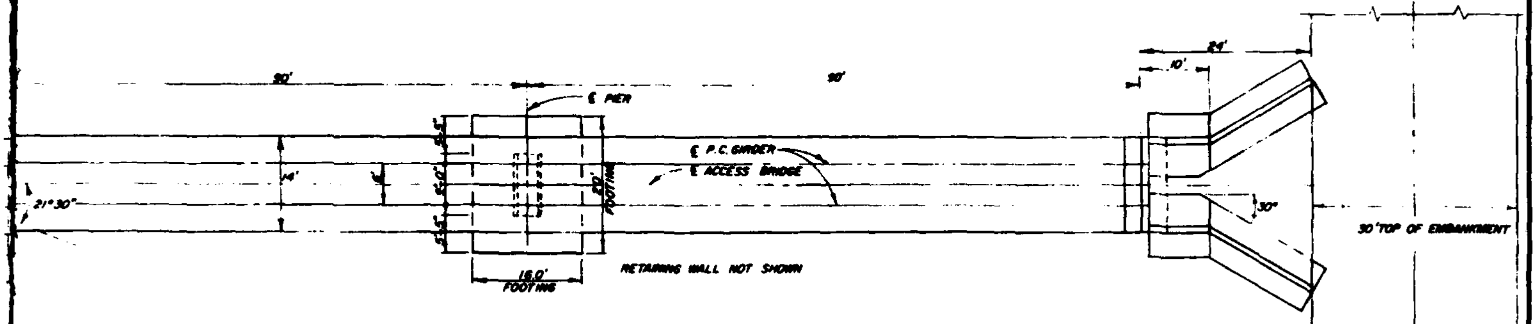


TYPICAL SECTION OF ACCESS BRIDGE
1/2 IN. = 1 FT.

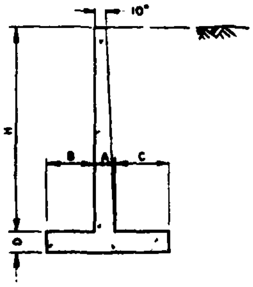
ALUE ENGINEERING PAYS



PROFILE OF ACCESS BRIDGE
1 IN. = 10 FT.

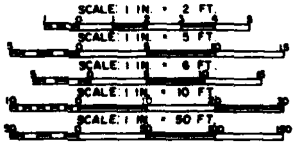


PLAN OF ACCESS BRIDGE
1 IN. = 10 FT.



TYPICAL WALL SECTION
AT ABUTMENT
1 IN. = 5 FT.

SECTION	H	A	B	C	D
B-B	14'-0"	1'-7"	3'-3"	6'-8"	1'-7"
C-C	10'-6"	1'-6"	2'-6"	4'-2"	1'-6"



SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:
D. CASTRO

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
ACCESS BRIDGE, PLANS AND SECTIONS

SUBMITTED BY:

DATE
APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

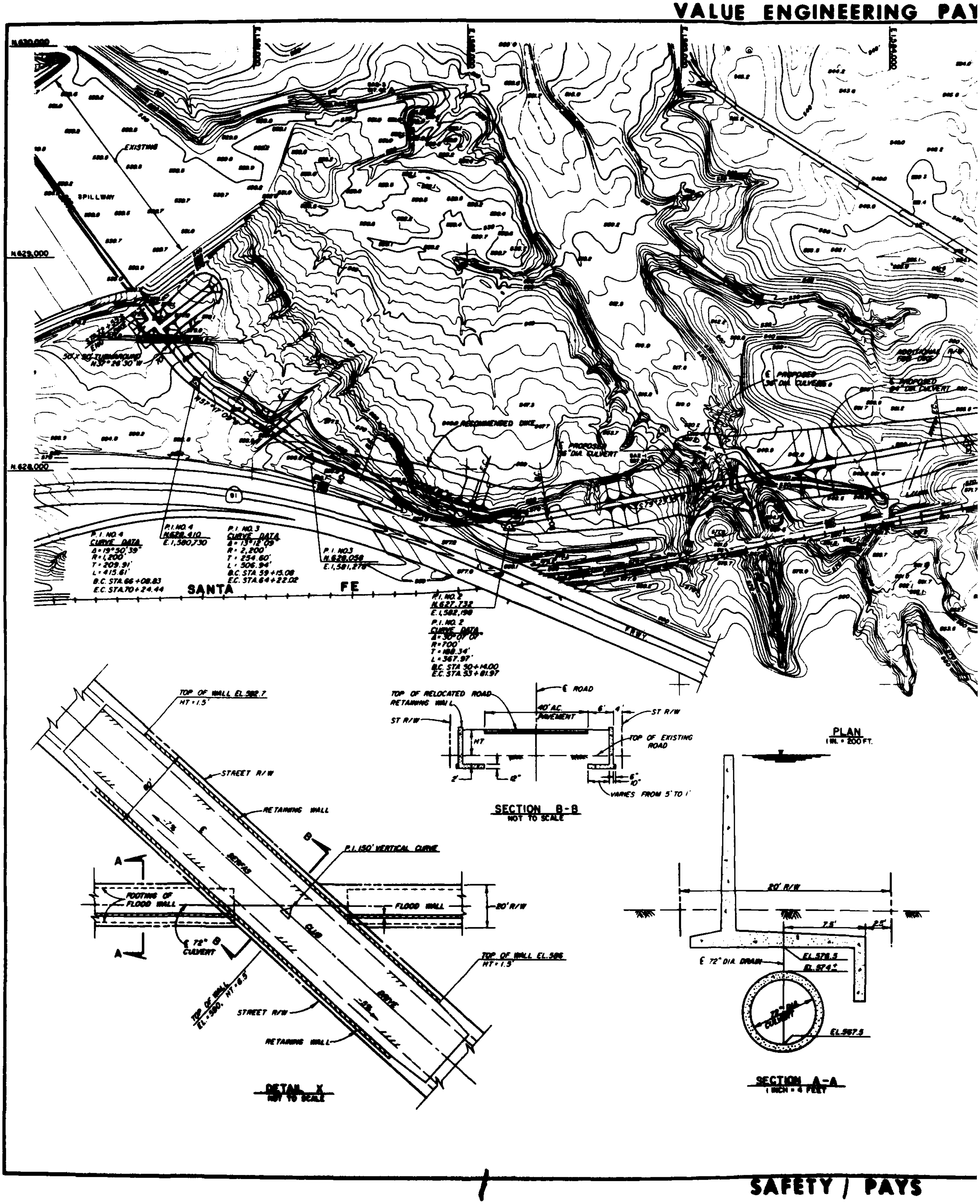
SHEET
1
OF
1

PLATE 10

SAFETY PAYS

1

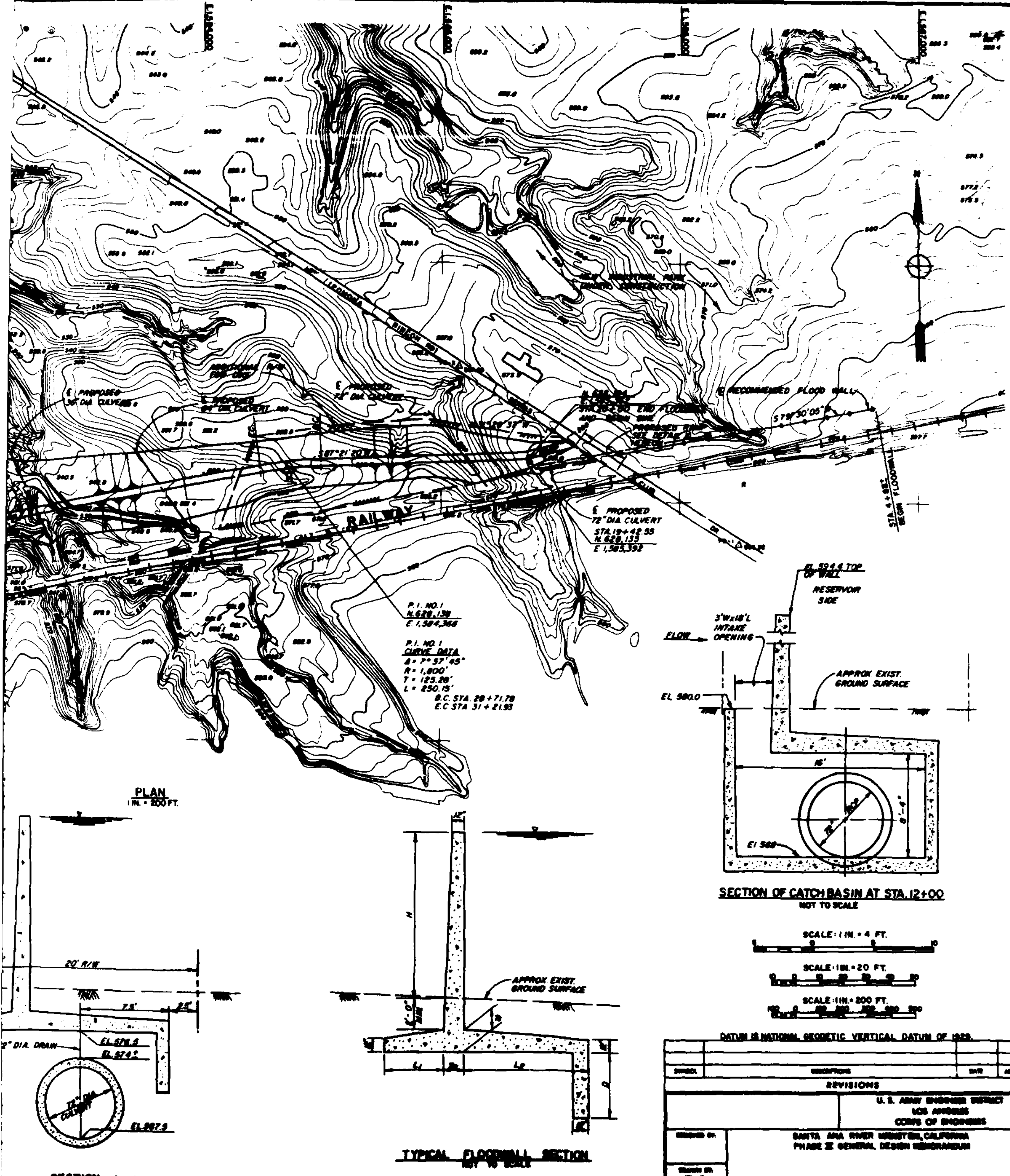
2


PLAN
1 IN. = 200 FT.

SECTION B-B
NOT TO SCALE

DETAIL X
NOT TO SCALE

SECTION A-A
1 INCH = 4 FEET



PLAN
1 IN. = 200 FT.

SECTION OF CATCH BASIN AT STA. 12+00
NOT TO SCALE

SECTION A-A
1 INCH = 4 FEET

TYPICAL FLOODWALL SECTION
NOT TO SCALE

FLOOD WALL DIMENSIONS					
H	Tw	Tb	L₁	L₂	D
6'	12"	12"	2'-6"	5'-6"	0
6' to 10'	12"	12"	2'-6"	6'-6"	3'-0"
10' to 14.5'	12"	18"	3'-0"	12'-6"	3'-0"

SCALE: 1 IN. = 4 FT.
5 0 5 10

SCALE: 1 IN. = 20 FT.
10 0 10 20 30 40 50

SCALE: 1 IN. = 200 FT.
100 0 100 200 300 400 500

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY: DC
CHECKED BY:

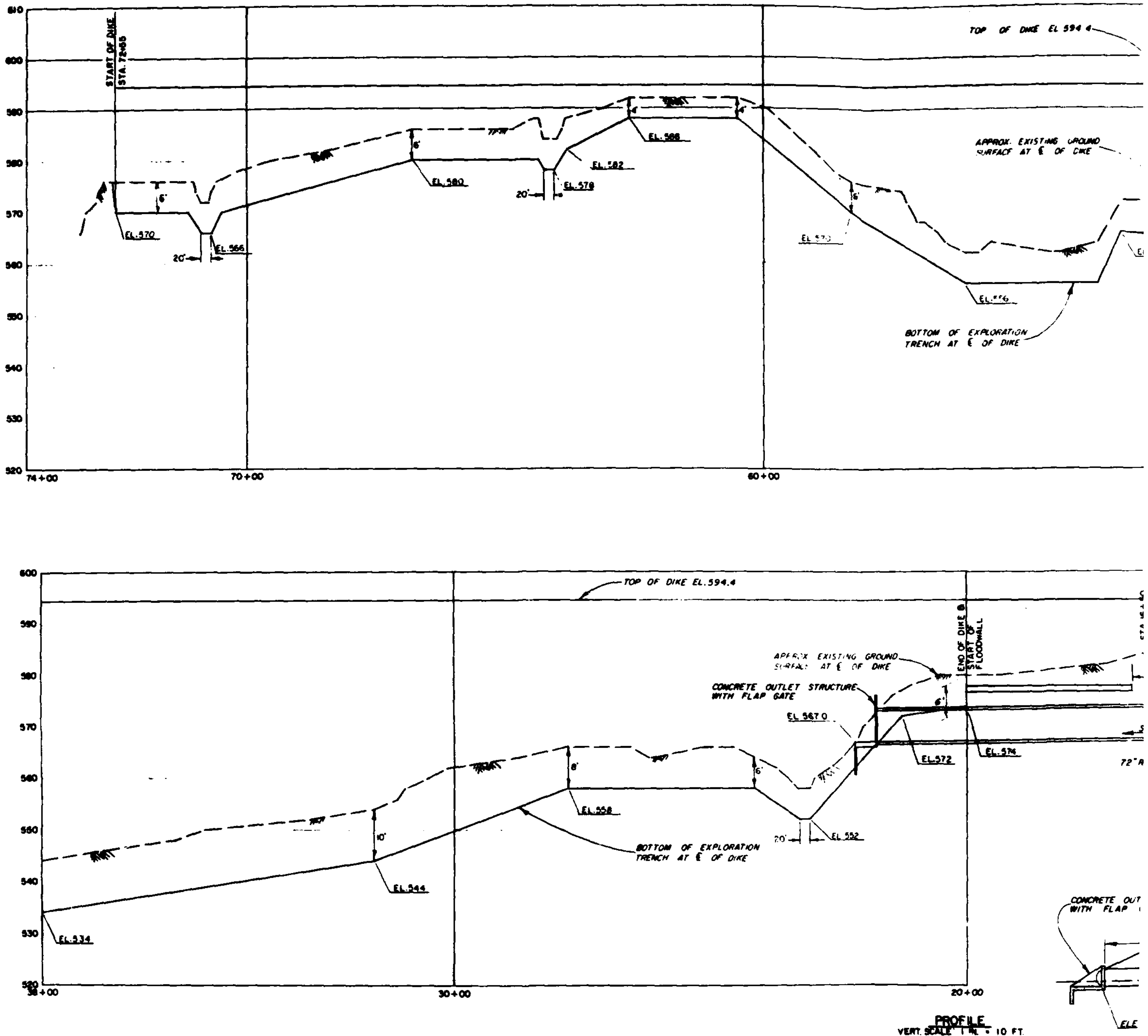
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
AUXILIARY DIKE
PLAN, DETAIL, AND SECTIONS

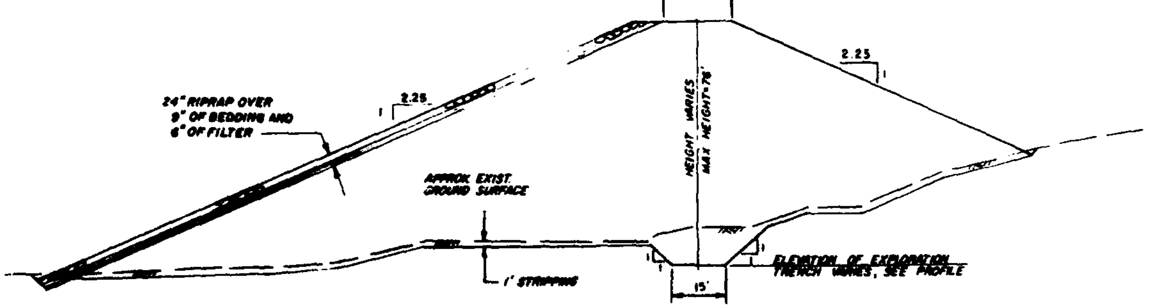
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-____
DISTRICT FILE NO.
SHEET 1 OF 1 SHEET

PLATE 11

2

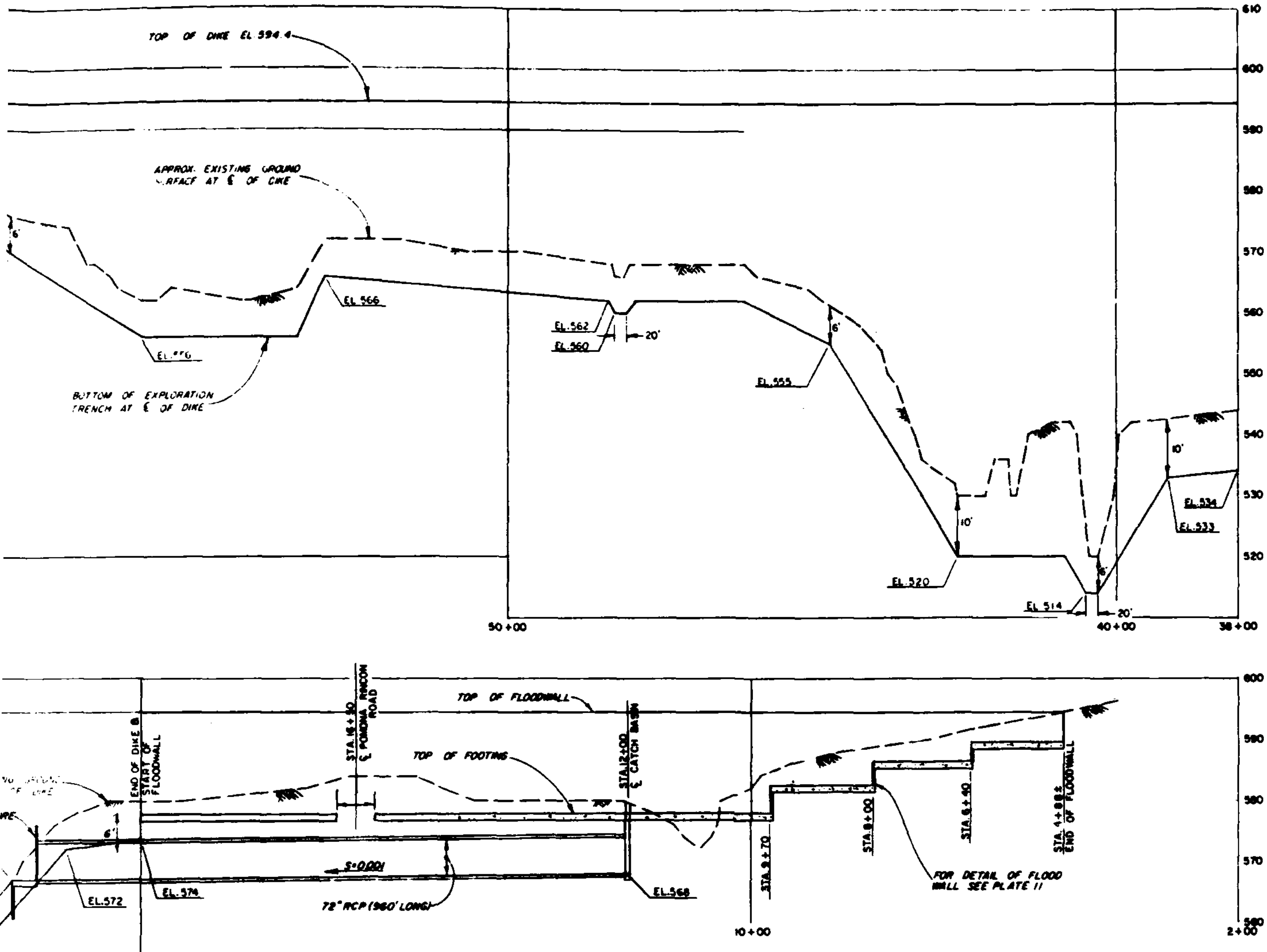


PROFILE
VERT. SCALE 1 IN. = 10 FT.
HORIZ. SCALE 1 IN. = 100 FT.

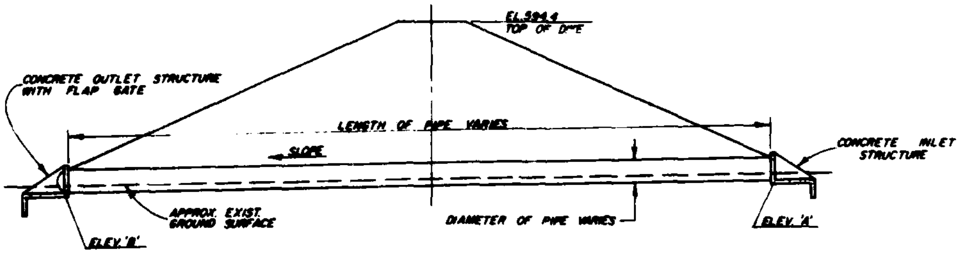


TYPICAL CROSS-SECTION FOR AUXILIARY DIKE
SCALE: 1 IN. = 20 FT.

UE ENGINEERING PAYS



PROFILE
VERT SCALE 1 IN = 10 FT
HORIZ SCALE 1 IN = 100 FT



TYPICAL CROSS SECTION AT CULVERT

CULVERT DATA					
STATION	DIA.	LENGTH	ELEV. 'A'	ELEV. 'B'	SLOPE
22+65	72"	164'	559.0	555.0	0.0244
35+45	84"	206'	548.0	544.5	0.0168
41+00	36"	274'	540.0	520.0	0.0730
42+90	36"	292'	544.0	524.0	0.0685

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY: D Cyrns
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

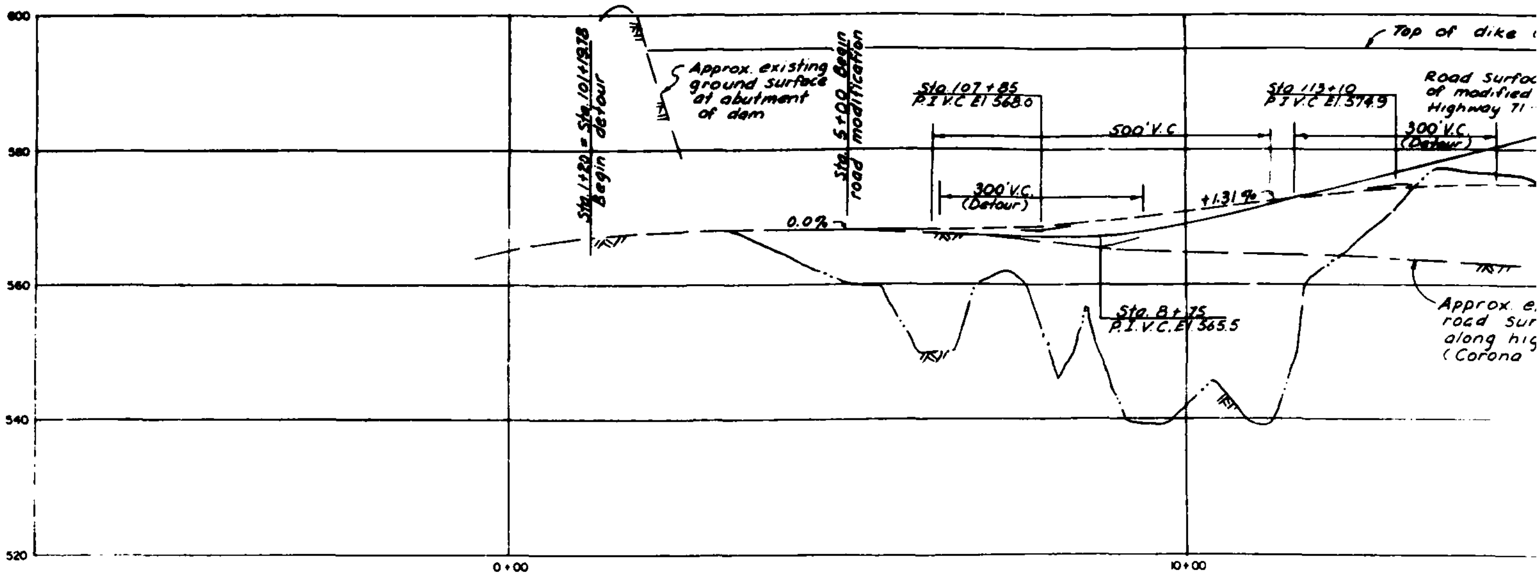
PRADO DAM
AUXILIARY DIKE
PROFILE AND SECTIONS

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____-B-____
DISTRICT FILE NO.
SHEET 1 OF 1 SHEETS

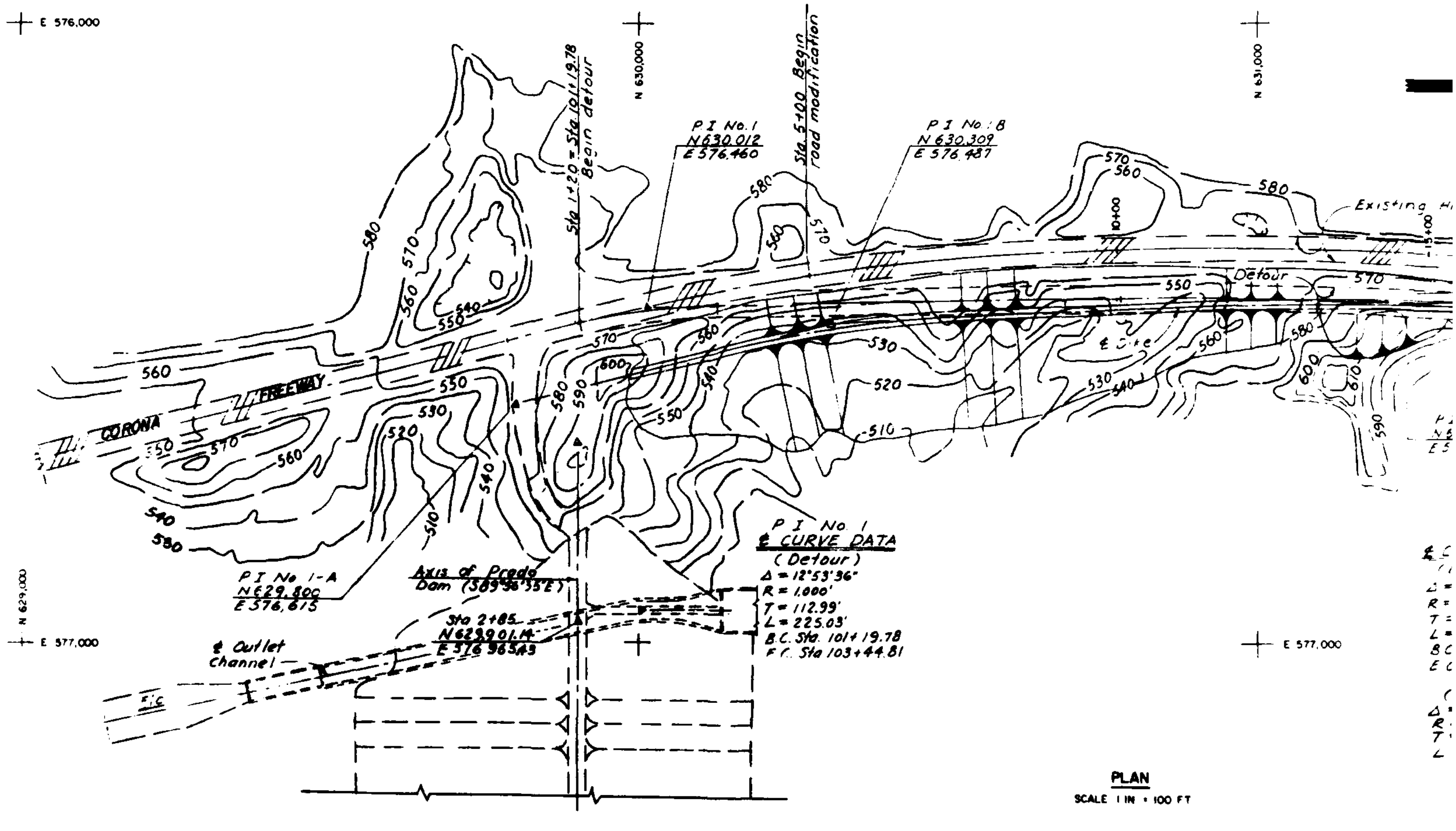
PLATE 12

SAFETY PAYS

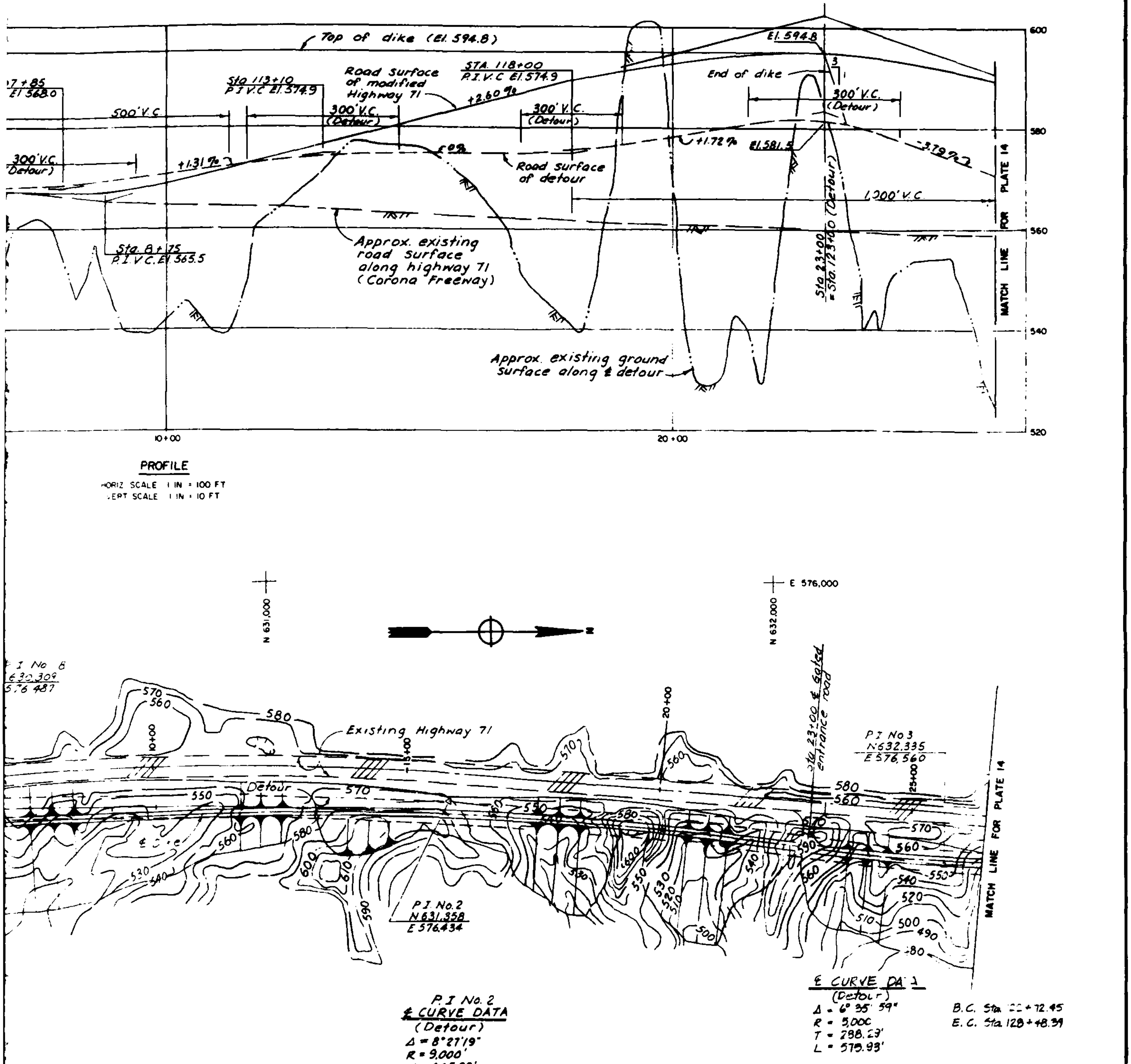
2



PROFILE
HORIZ SCALE 1 IN = 100 FT
VERT SCALE 1 IN = 10 FT



PLAN
SCALE 1 IN = 100 FT



P.I No. 2
℄ CURVE DATA
(Detour)
Δ = 8°27'19"
R = 9,000'
T = 665.28'
L = 1,328.15'
B.C. Sta. 109+12.78
E.C. Sta. 122+40.93

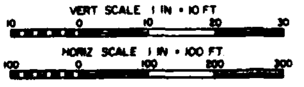
(Dike)
Δ = 10°14'28"
R = 6,000'
T = 357.66'
L = 1,024.11'

℄ CURVE DA
(Detour)
Δ = 6° 35' 59"
R = 5,000
T = 288.23'
L = 575.93'

B.C. Sta. 22+72.45
E.C. Sta. 128+48.39

E 577,000

PLAN
SCALE 1 IN = 100 FT



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

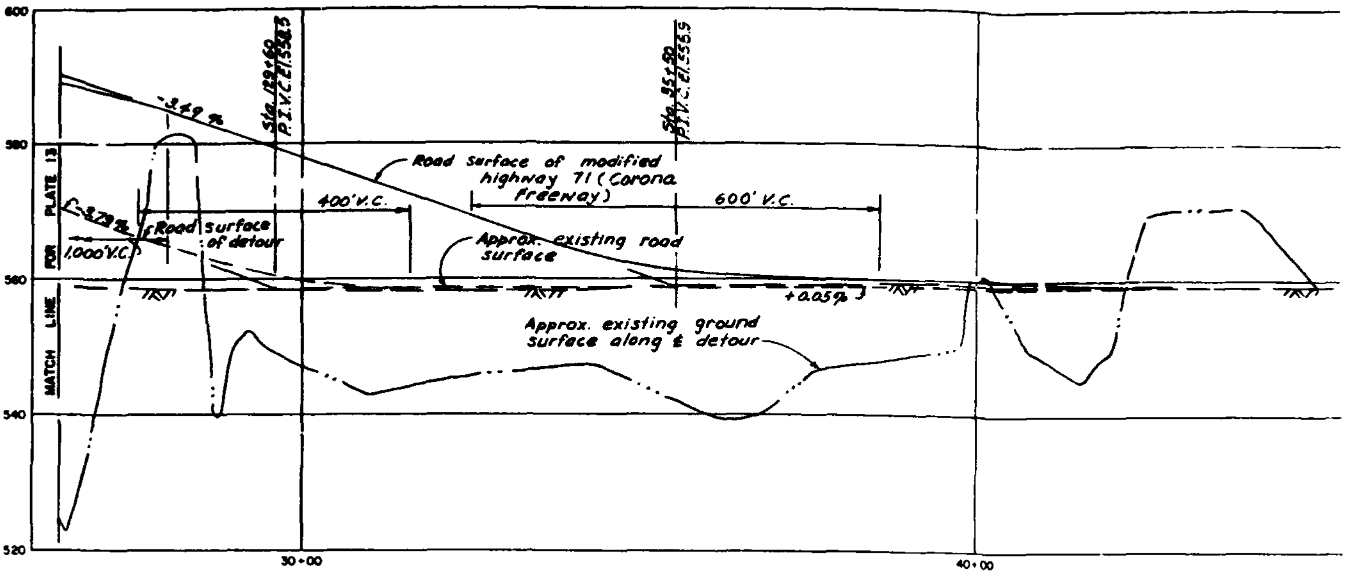
PRADO DAM
MODIFICATION OF CORONA EXPRESSWAY
PLAN AND PROFILE

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET 1 OF 2

PLATE 13

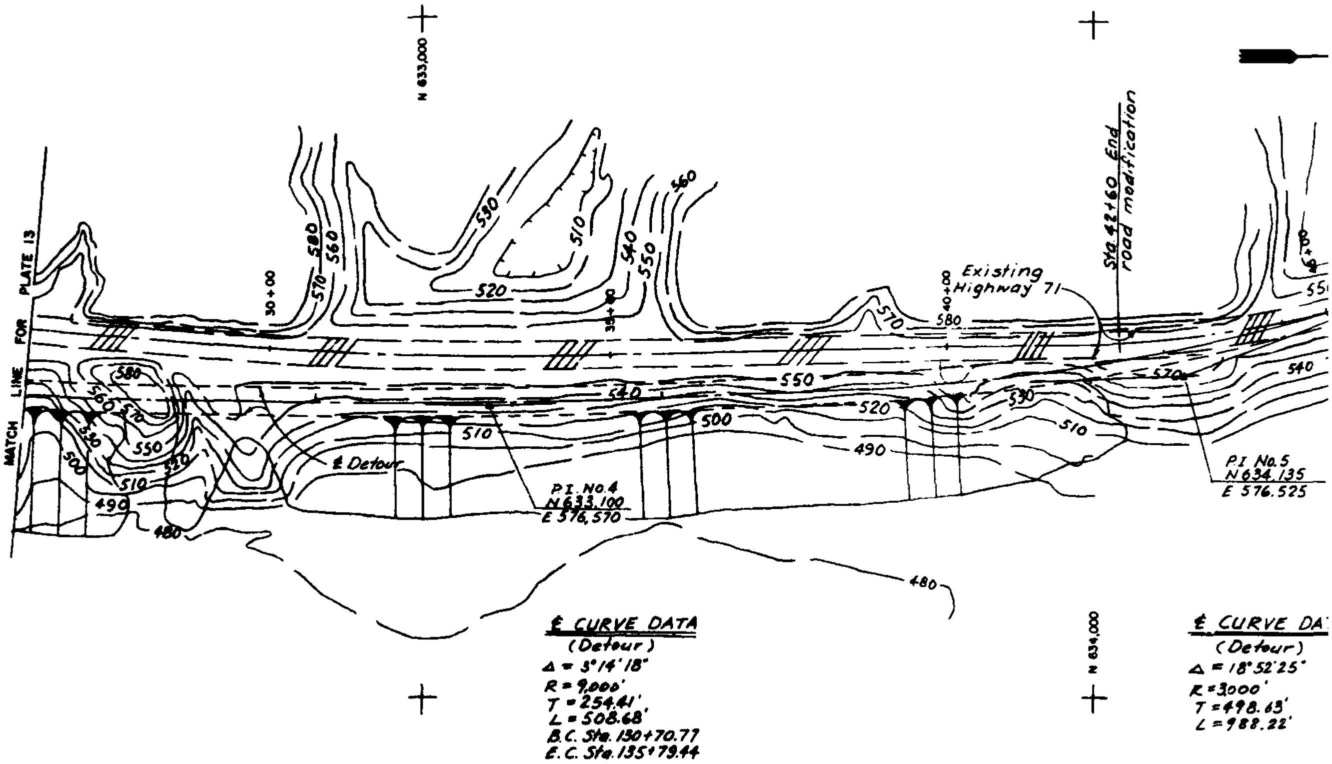
2

VALUE ENGINEERING P



PROFILE

HORIZ SCALE 1 IN = 100 FT
VERT SCALE 1 IN = 10 FT

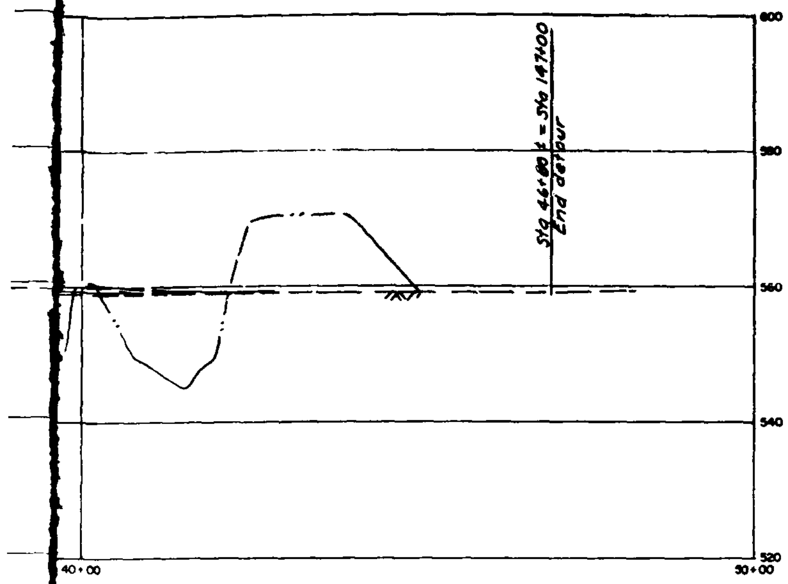


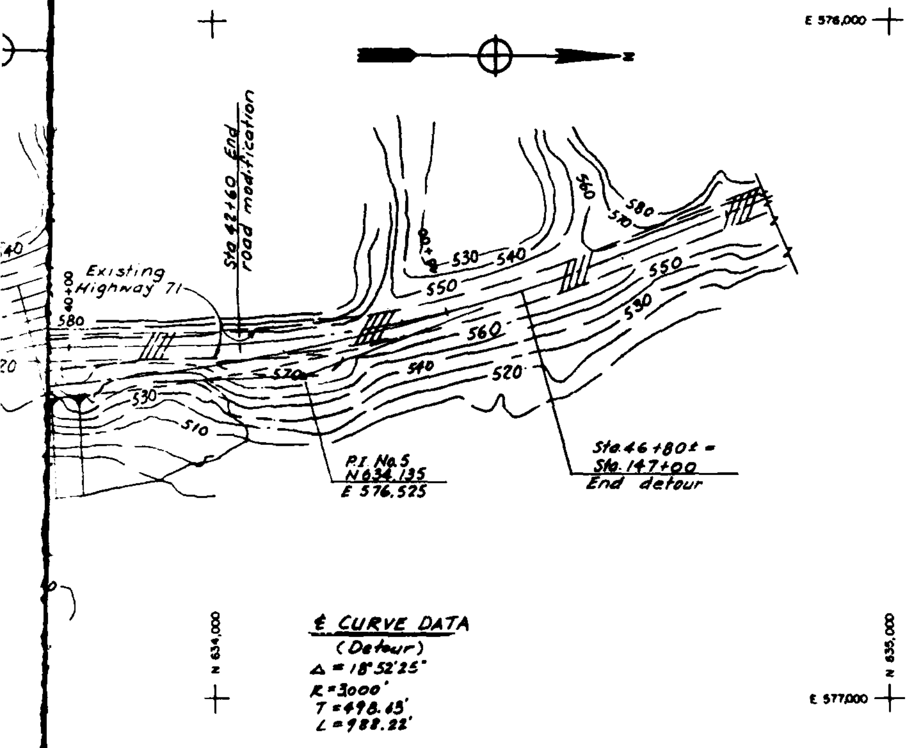
PLAN

SCALE 1 IN = 100 FT

SAFETY PAYS

S LUE ENGINEERING PAYS





0 FT

VERT. SCALE: 1 IN. = 10 FT
10 0 10 20 30

HORIZ. SCALE: 1 IN. = 100 FT.
100 0 100 200 300

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
MODIFICATION OF CORONA EXPRESSWAY
PLAN AND PROFILE

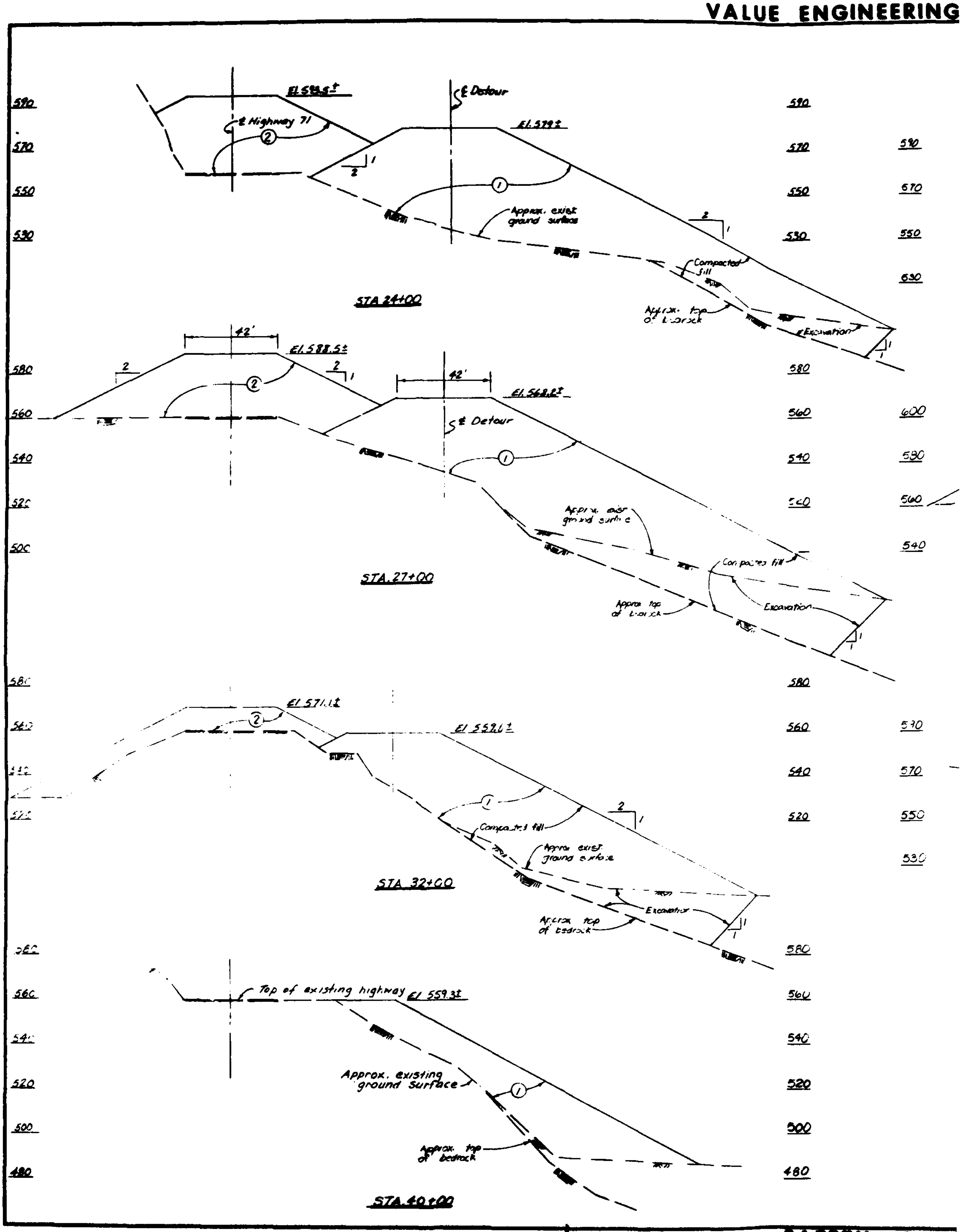
SUBMITTED BY:
DATE APPROVED
SPEC. NO. DACW09-____-B-____
DISTRICT FILE NO.
SHEET 2 OF 2

PLATE 14

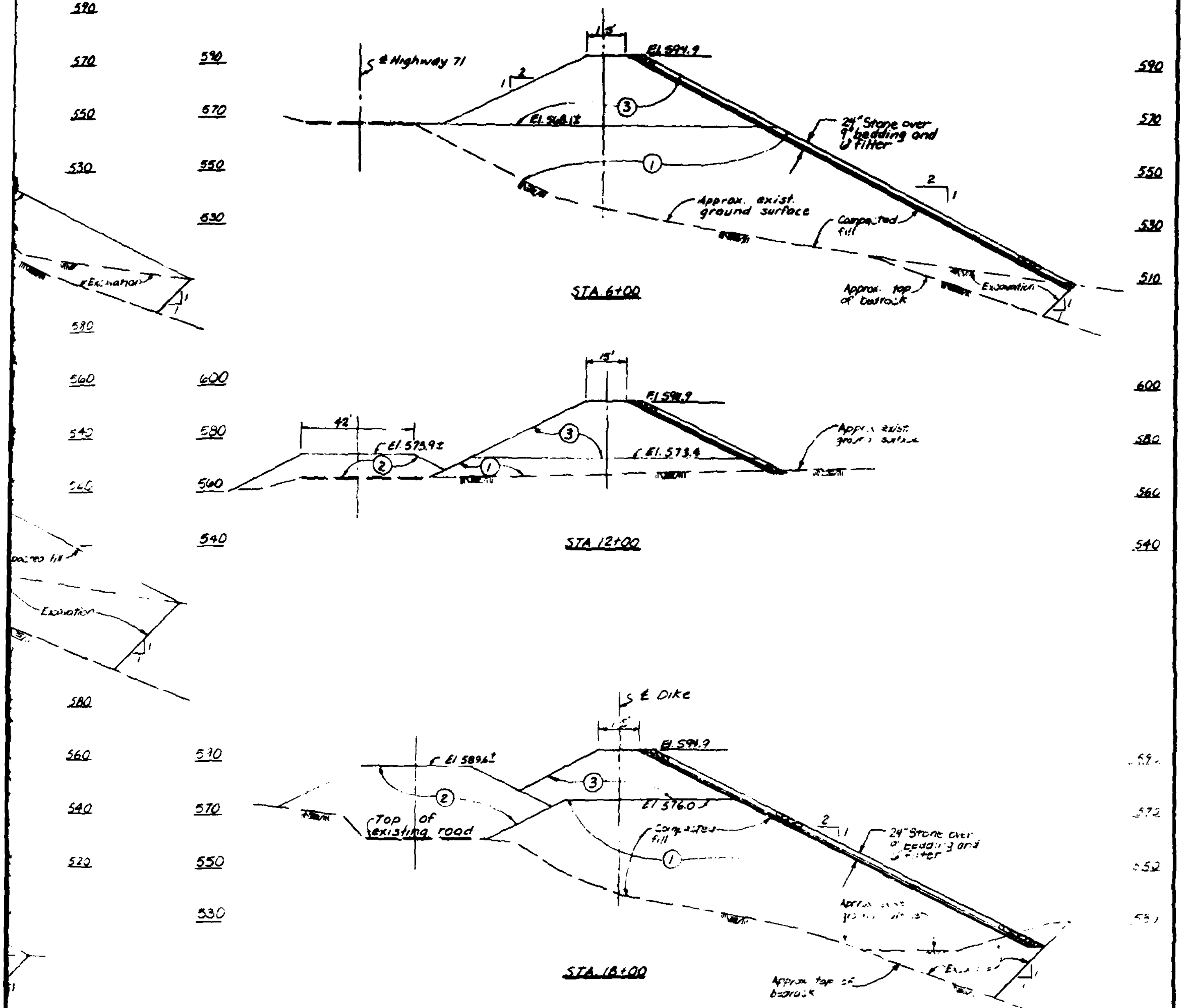
SAFETY PAYS

2

VALUE ENGINEERING



SAFETY PAY



LEGEND

① FIRST STAGE — CONSTRUCTION OF DETOUR

② SECOND STAGE — CONSTRUCTION OF HIGHWAY 71

③ THIRD STAGE — CONSTRUCTION OF DIKE

580
560
540
520
500
480

NOTES:

1. ALL CROSS SECTIONS ARE DRAWN LOOKING UPSTREAM
2. SCALE: 1" = 20'
3. LIMIT OF 24" STONE OVER 9" BEDDING AND 6" FILTER IS BETWEEN STA. 1+70 AND STA. 23+00.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

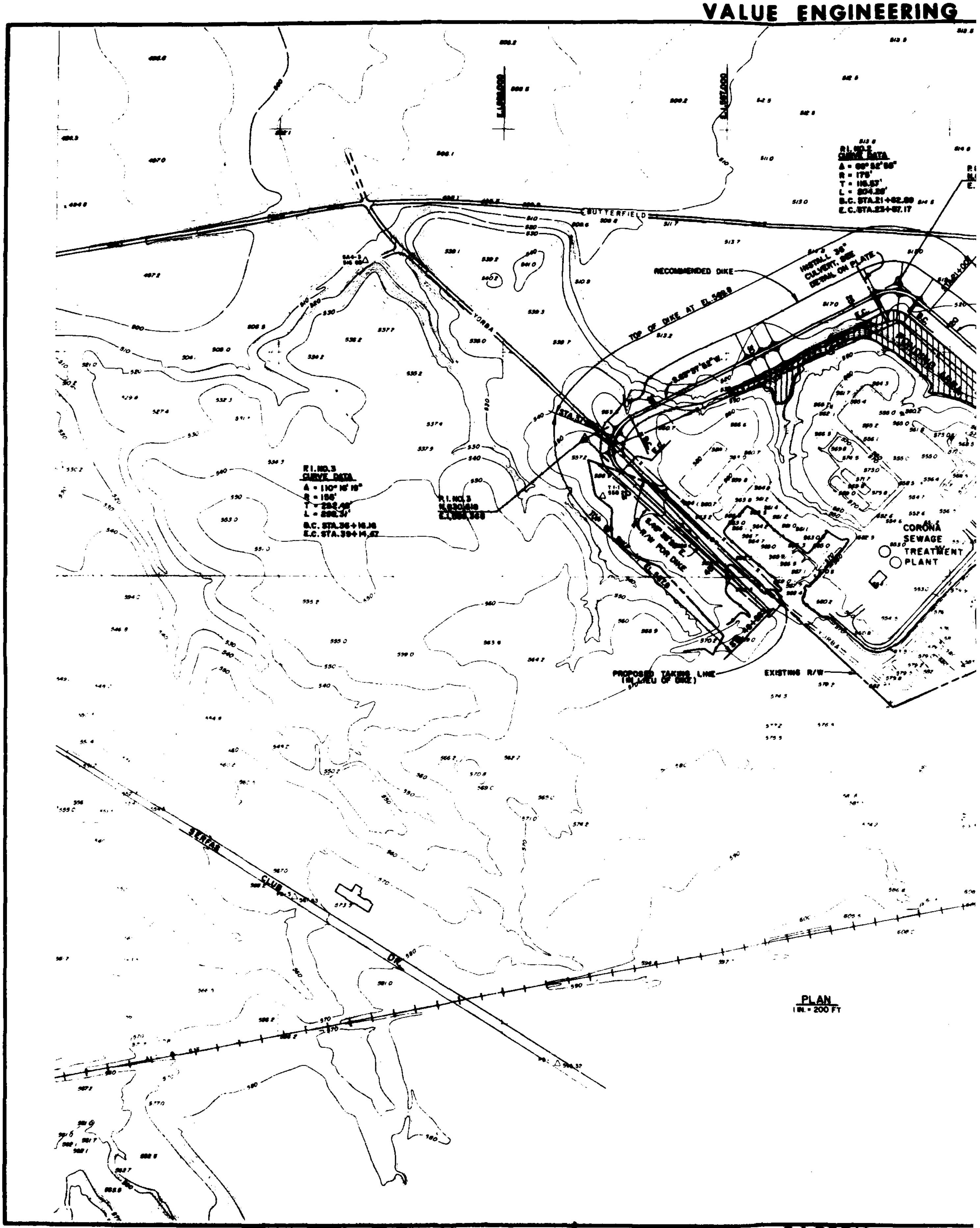
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
MODIFICATION OF CORONA FREEWAY
TYPICAL CROSS SECTIONS

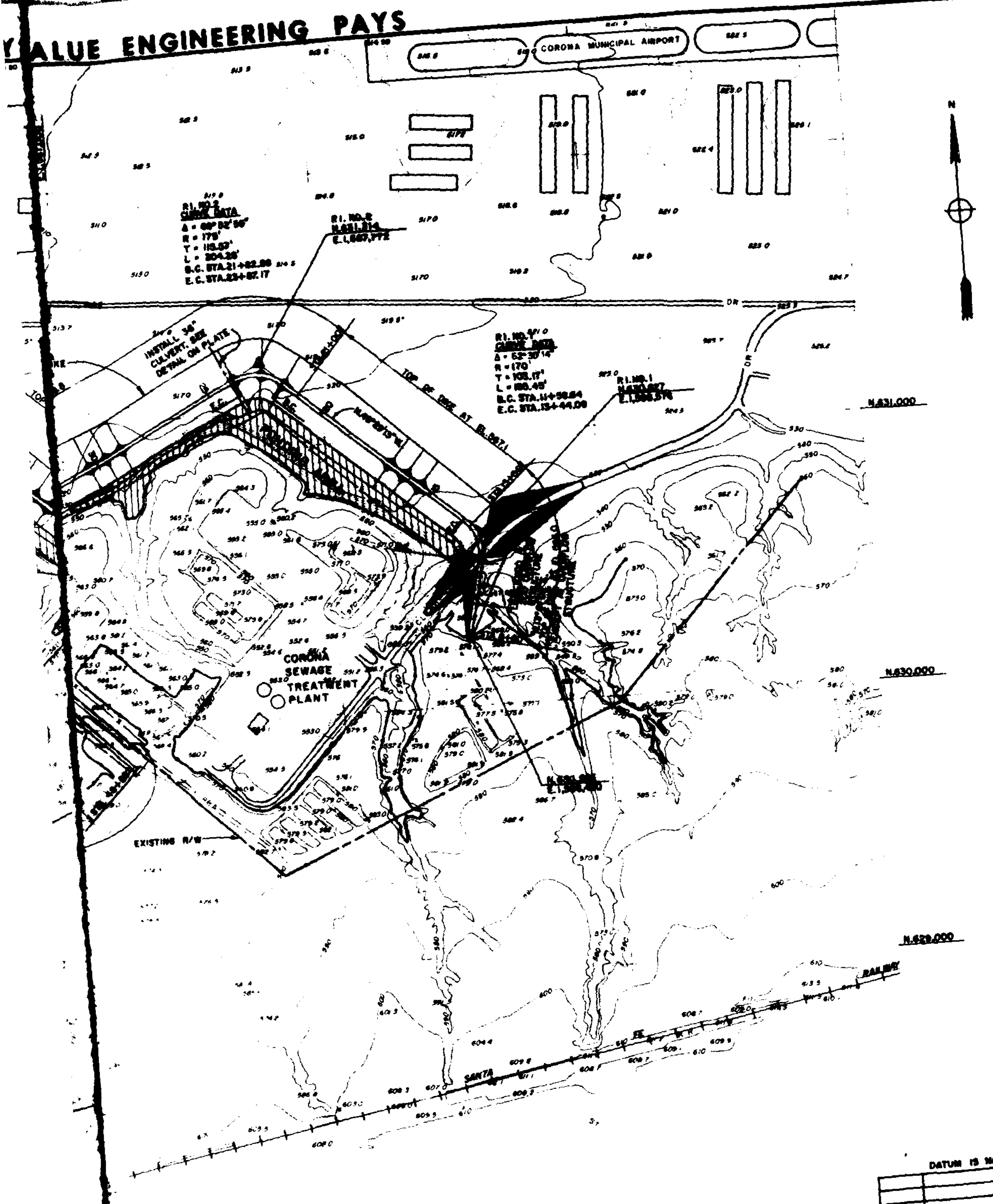
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW 09-____ B-____
DISTRICT FILE NO.
SHEET 1 OF 1

PLATE 15

2


P.I. NO.2
CURVE DATA
Δ = 66° 32' 56"
R = 175'
T = 116.57'
L = 204.26'
B.C. STA.21+62.89
E.C. STA.23+67.17
BUTTERFIELD
YORBA
RECOMMENDED DIKE
INSTALL 36" CULVERT, SEE DETAIL ON PLATE
TOP OF DIKE AT EL. 549.8
P.I. NO.3
CURVE DATA
Δ = 110° 16' 19"
R = 156'
T = 222.46'
L = 298.31'
B.C. STA.36+16.16
E.C. STA.39+14.47
P.I. NO.3
N.630,618
E.1,508,368
CORONA
SEWAGE
TREATMENT
PLANT
R/W FOR DIKE
PROPOSED TAKING LINE (IN LIEU OF DIKE)
EXISTING R/W
SERFAS CLUB DR
510
520
530
540
550
560
570
580
590
PLAN
1 IN. = 200 FT

VALUE ENGINEERING PAYS



PLAN
1 IN. = 200 FT

GENERAL NOTES:
1. FOR VICINITY MAP, SEE PLATE 2
2. FOR PROFILE AND TYPICAL SECTION OF DIKE, SEE PLATE 17
3. FOR OVERFLOW STRUCTURE DETAIL, SEE PLATE 17

SCALE 1 IN. = 200 FT

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

DESIGNED BY:
DRAWN BY: LBA
CHECKED BY:

PRADO DAM
DIKE AT CORONA SEWAGE TREATMENT
PLANT-PLAN

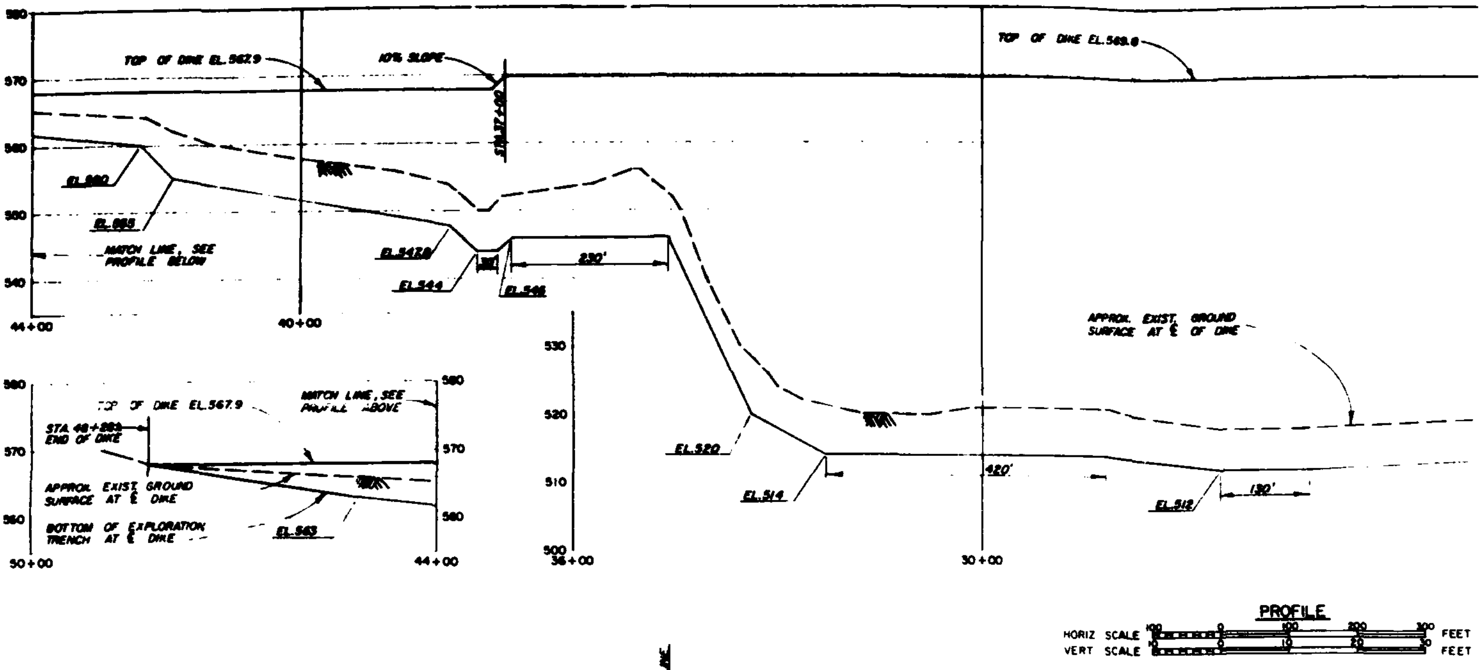
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____-B-____
DISTRICT FILE NO.
SHEET 1 OF 1

PLATE 16

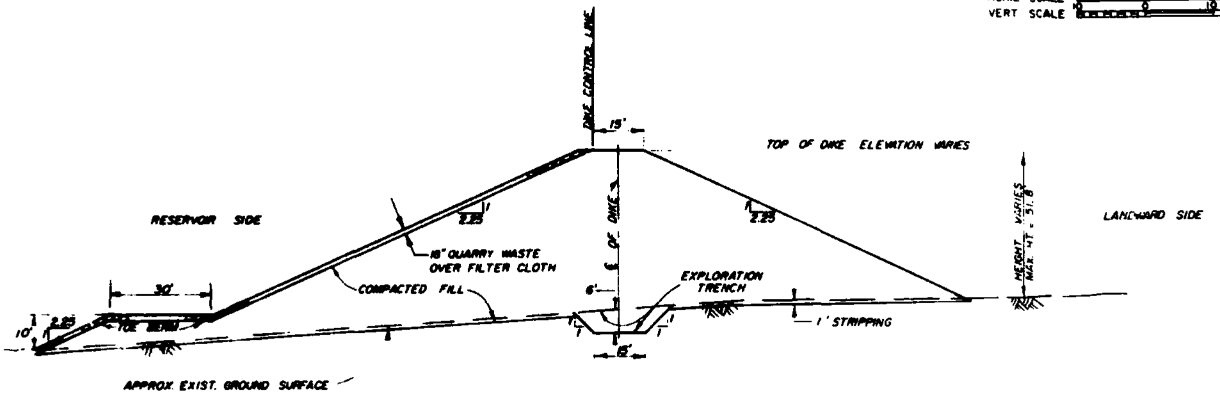
2

SAFETY PAYS

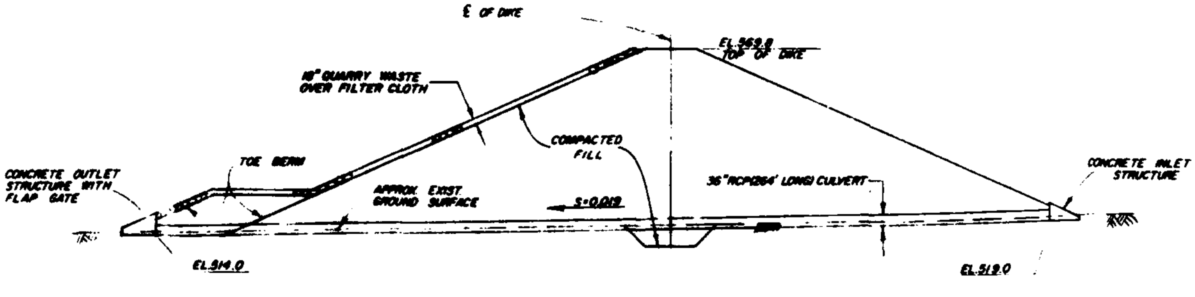
VALUE ENGINEERING P



PROFILE



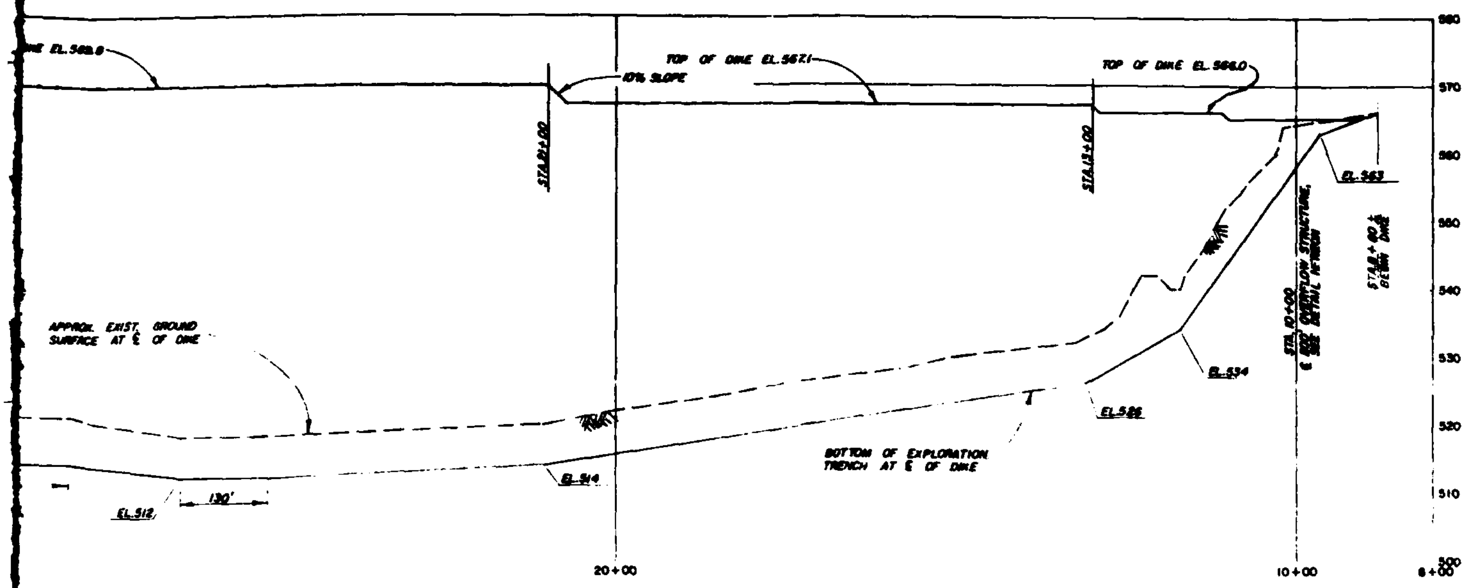
TYPICAL CROSS SECTION
AT CORONA SEWAGE TREATMENT PLANT
SCALE: 1 IN. = 20 FT.



36" CULVERT AT STA.23+80
SCALE: 1 IN. = 20 FT.

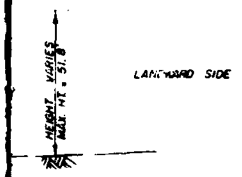
SAFETY PAYS

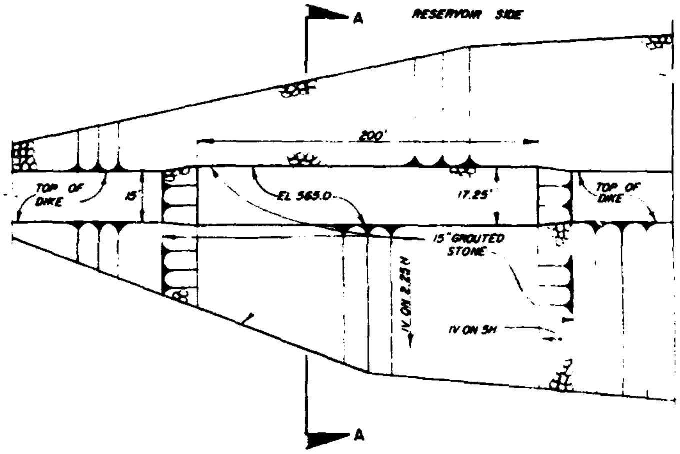
LUE ENGINEERING PAYS



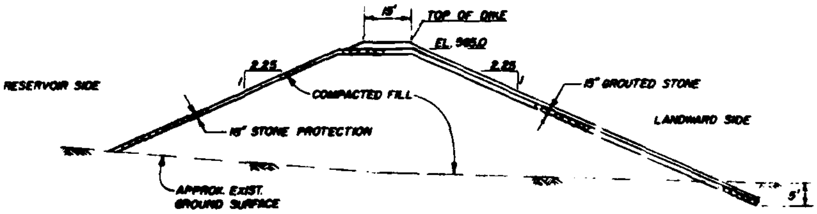
PROFILE

HORIZ SCALE 100 0 100 200 300 FEET
VERT SCALE 10 0 10 20 30 FEET



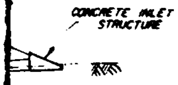


PLAN



SECTION A-A
OVERFLOW STRUCTURE DETAIL

NOT TO SCALE



GENERAL NOTES:
1. FOR VICINITY MAP, SEE PLATE 2.
2. FOR PLAN OF DIKE, SEE PLATE 16.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

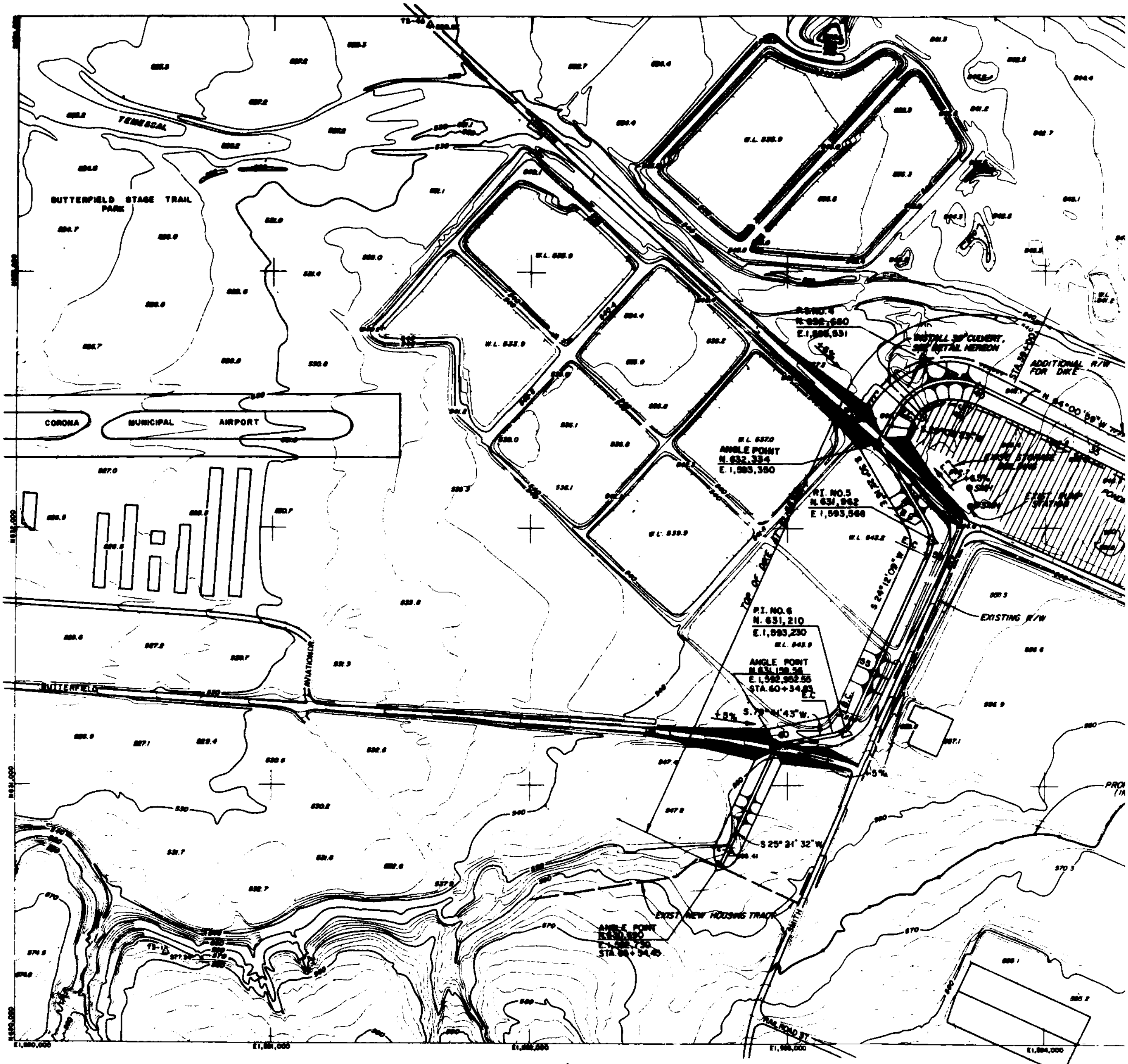
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
DIKE AT CORONA SEWAGE
TREATMENT PLANT, PROFILE AND SECTIONS

CHECKED BY:
DRAWN BY: DC
CHECKED BY:
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET 1 OF 1

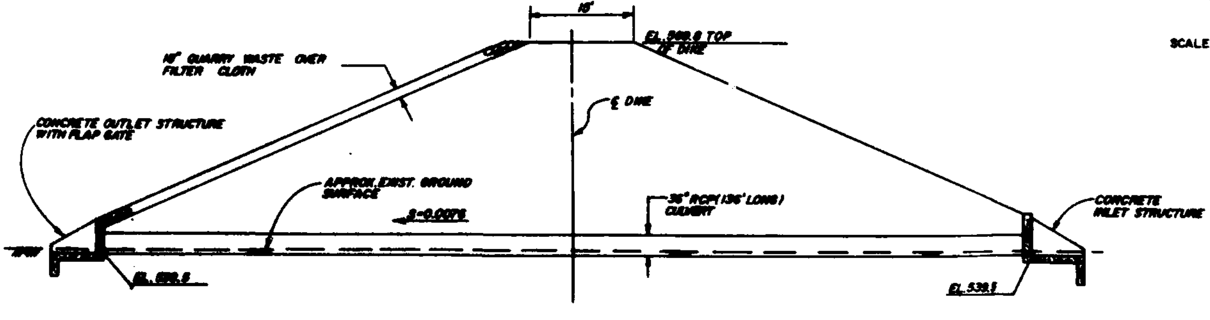
PLATE 17

SAFETY PAYS



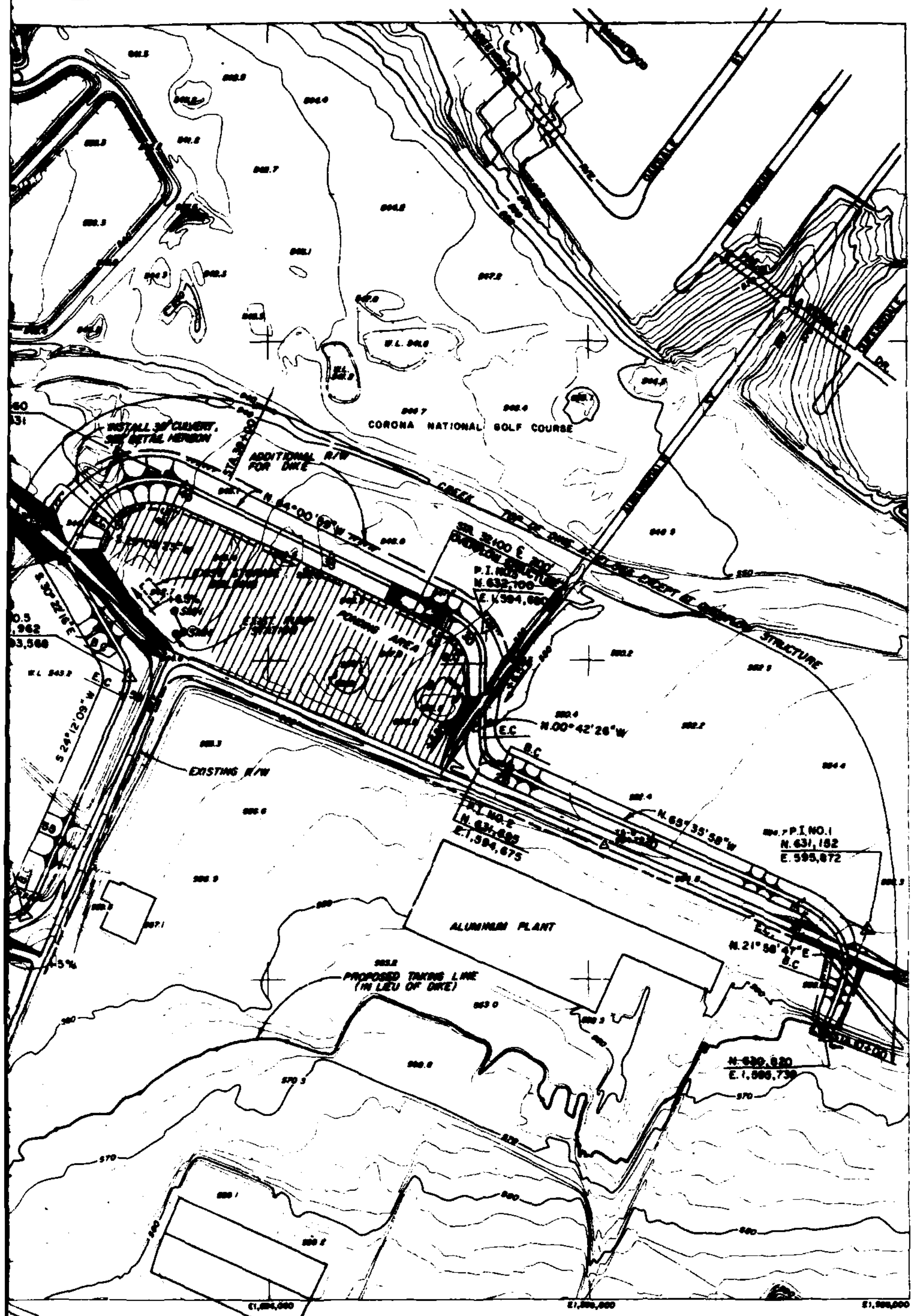
PLA

SCALE 100 0 100 200



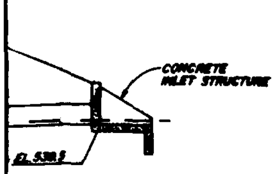
36" CULVERT AT STA. 43+20
SCALE 1 IN. = 10 FT.

Orthophotomap Wild Aviophot [illegible]
FROM PHOTOGRAPHY DATED JULY [illegible], 1970 AND [illegible]
AUG. [illegible], 1970
AERIAL SURVEYS, INC.



PLAN

SCALE 100 0 100 200 300 400 500 FEET



CURVE DATA

P.I. NO.	Δ	R	T	L
1	87°34'45"	210'	201.31'	320.99
2	66°18'24"	90'	58.79'	104.15'
3	64°43'28"	175'	110.89	197.69'
4	86°56'38"	245'	232.27'	371.78'
5	54°34'25"	140'	72.22'	133.35
6	55°29'34"	100'	52.60	96.85

P.I. NO.	B.C. STA.	E.C. STA.
1	11+56.71	14+77.70
2	25+32.01	26+36.16
3	28+71.51	30+69.20
4	40+04.24	43+76.02
5	48+75.58	50+08.93
6	57+08.58	58+05.43

GENERAL NOTES:

1. FOR VICINITY MAP, SEE PLATE 2.
2. FOR PROFILE AND TYPICAL SECTION OF DIKE, SEE PLATE 19.
3. FOR OVERFLOW STRUCTURE DETAIL, SEE PLATE 17.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

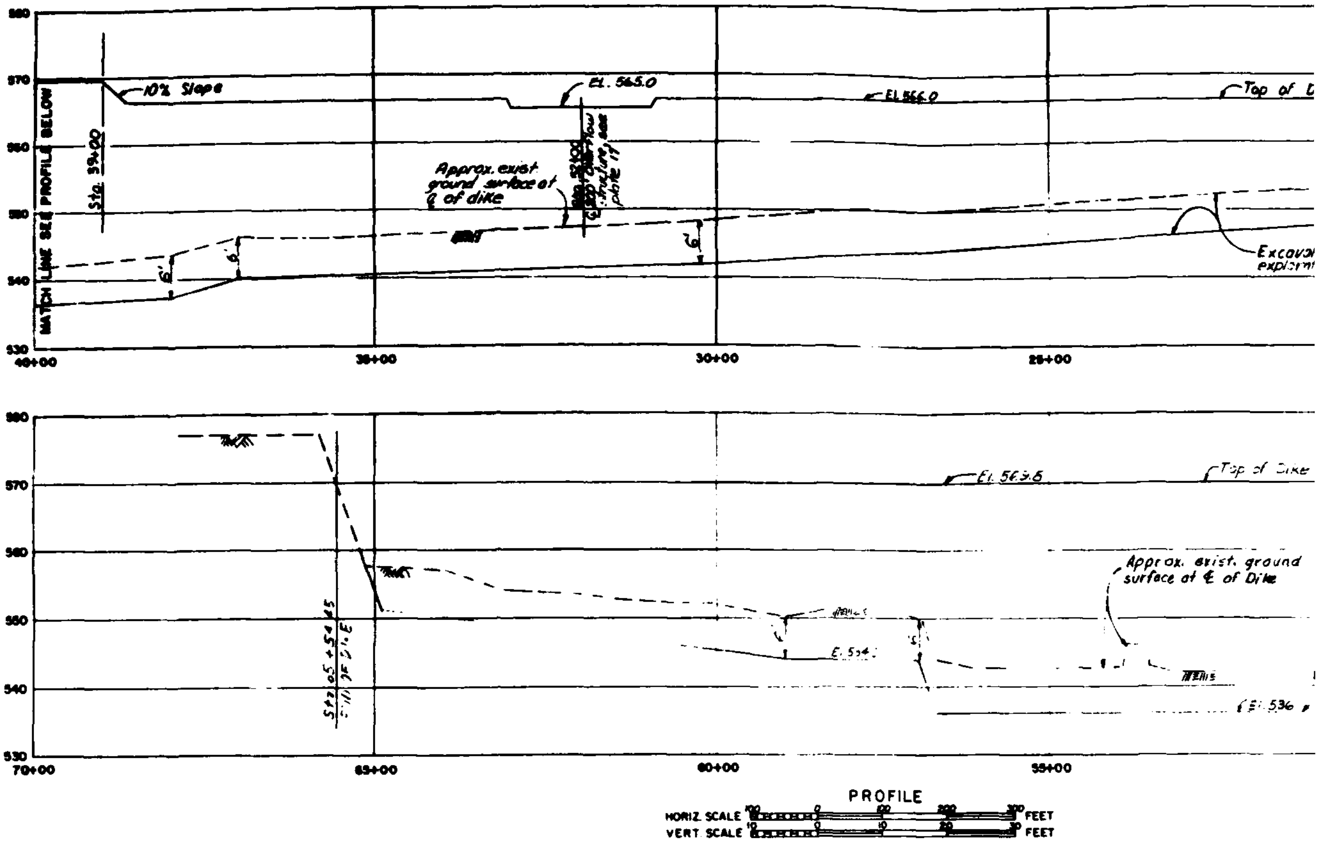
DEPARTMENT OF THE ARMY
LOS ANGELES DISTRICT CORPS OF ENGINEERS
LOS ANGELES, CALIFORNIA

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

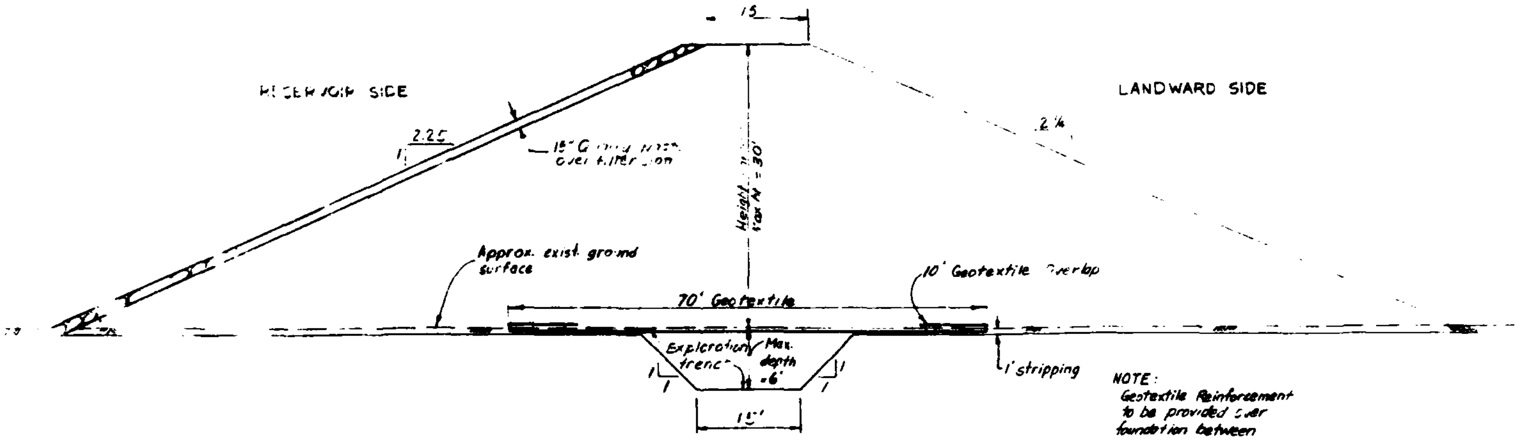
PRADO DAM
DIKE AT ALCOA ALUMINUM PLANT
PLAN

SCALE: 1"=200' C.I.: 2'

2



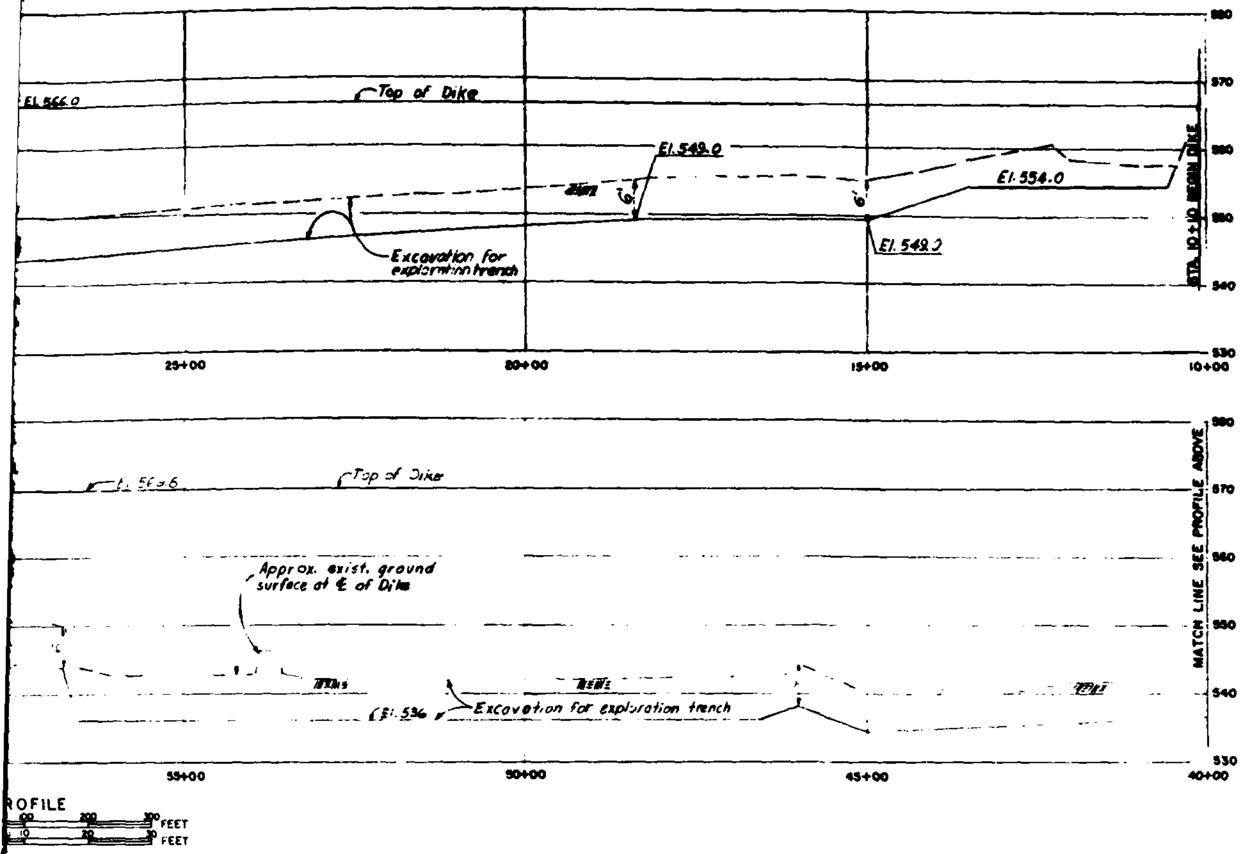
PROFILE

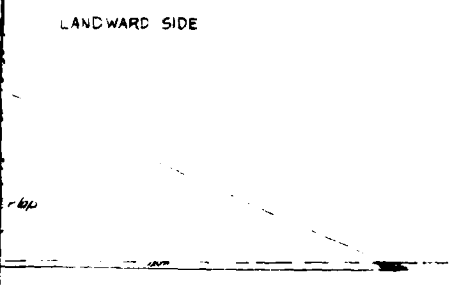


NOTE:
Geotextile Reinforcement to be provided over foundation between Sta 52+00 and Sta. 61+00.

TYPICAL CROSS SECTION
AT ALCOA ALUMINUM PLANT
NOT TO SCALE

GE





NOTE:
Geotextile Reinforcement to be provided over foundation between Sta. 52+00 and Sta. 61+00.

GENERAL NOTES:

1. FOR VICINITY MAP, SEE PLATE 2.
2. FOR PLAN OF DIKE, SEE PLATE 18.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

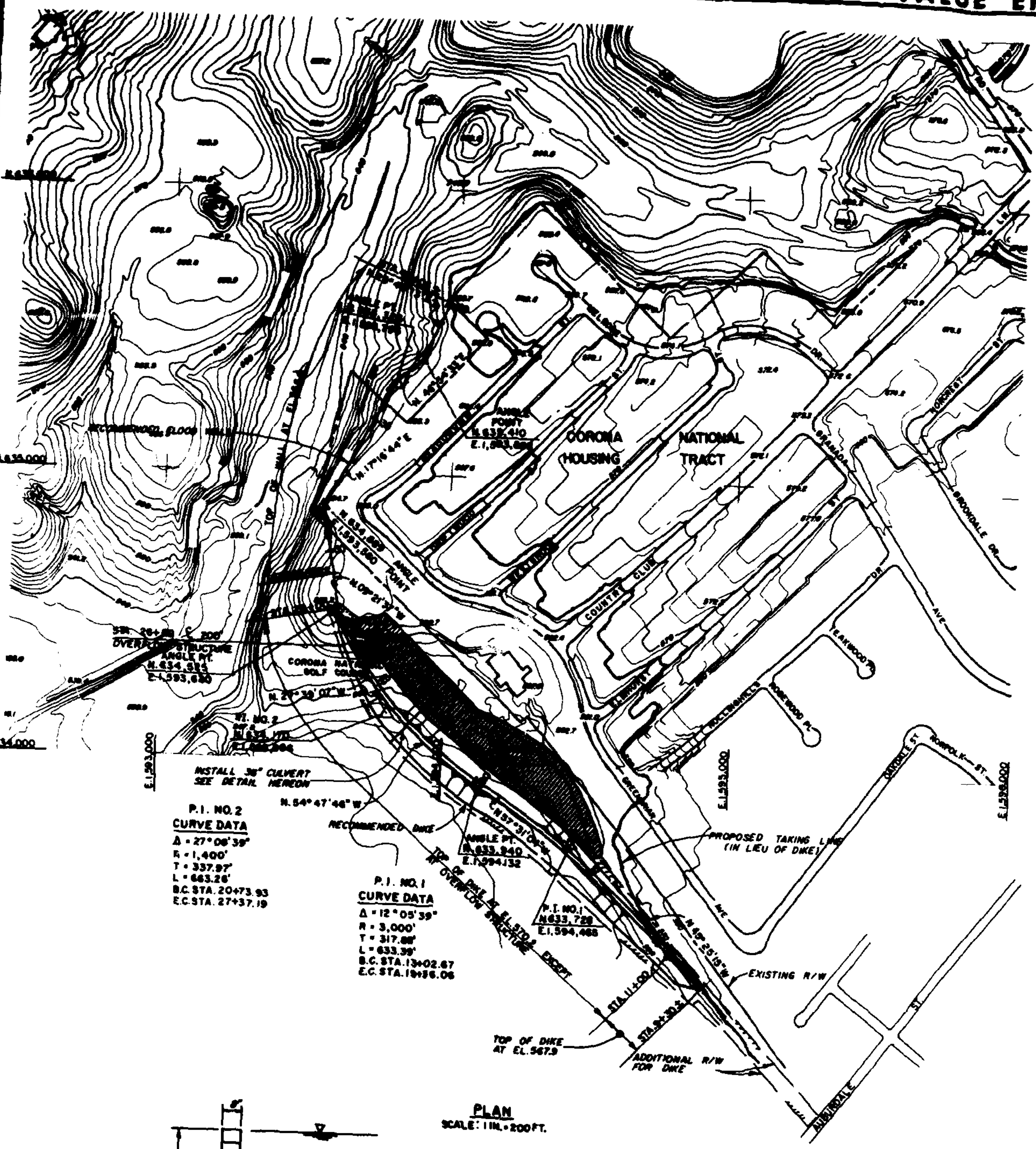
DESIGNED BY:
DRAWN BY: K. Z.
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
DIKE AT ALCOA ALUMINUM PLANT
PROFILE AND SECTIONS

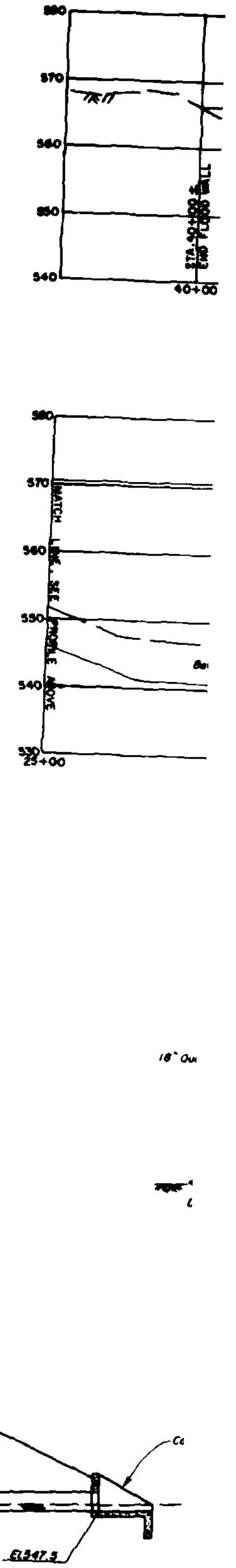
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET 1 OF 1 SHEET
PLATE 19

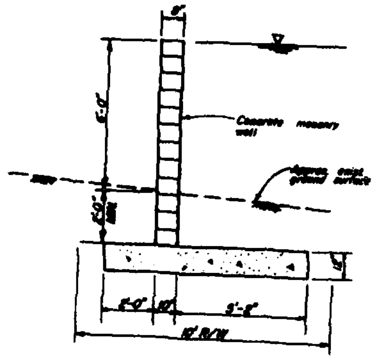
2



PLAN

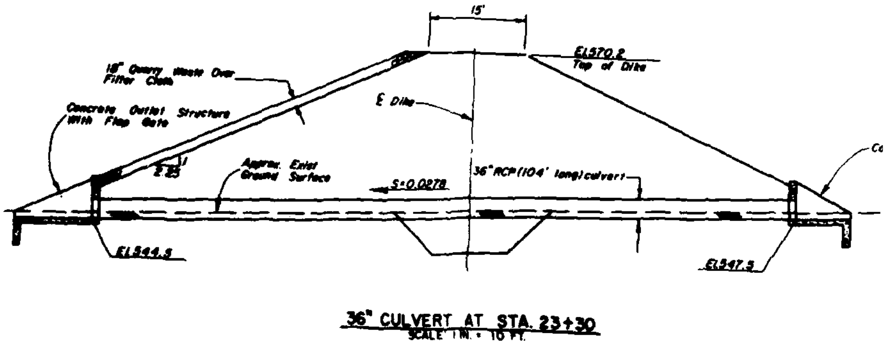
SCALE: 1 IN. = 200 FT.





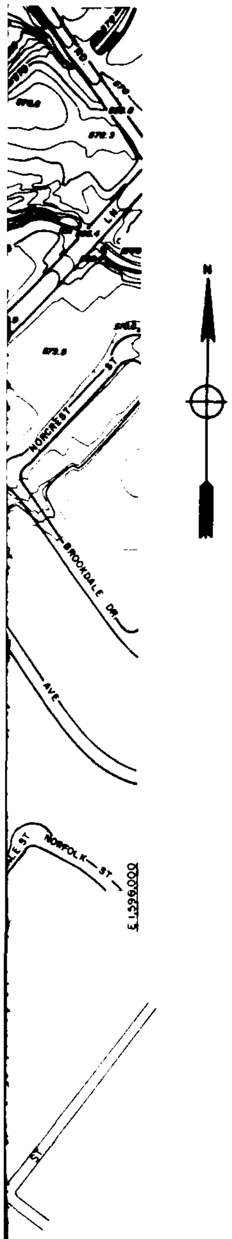
TYPICAL FLOOD WALL SECTION

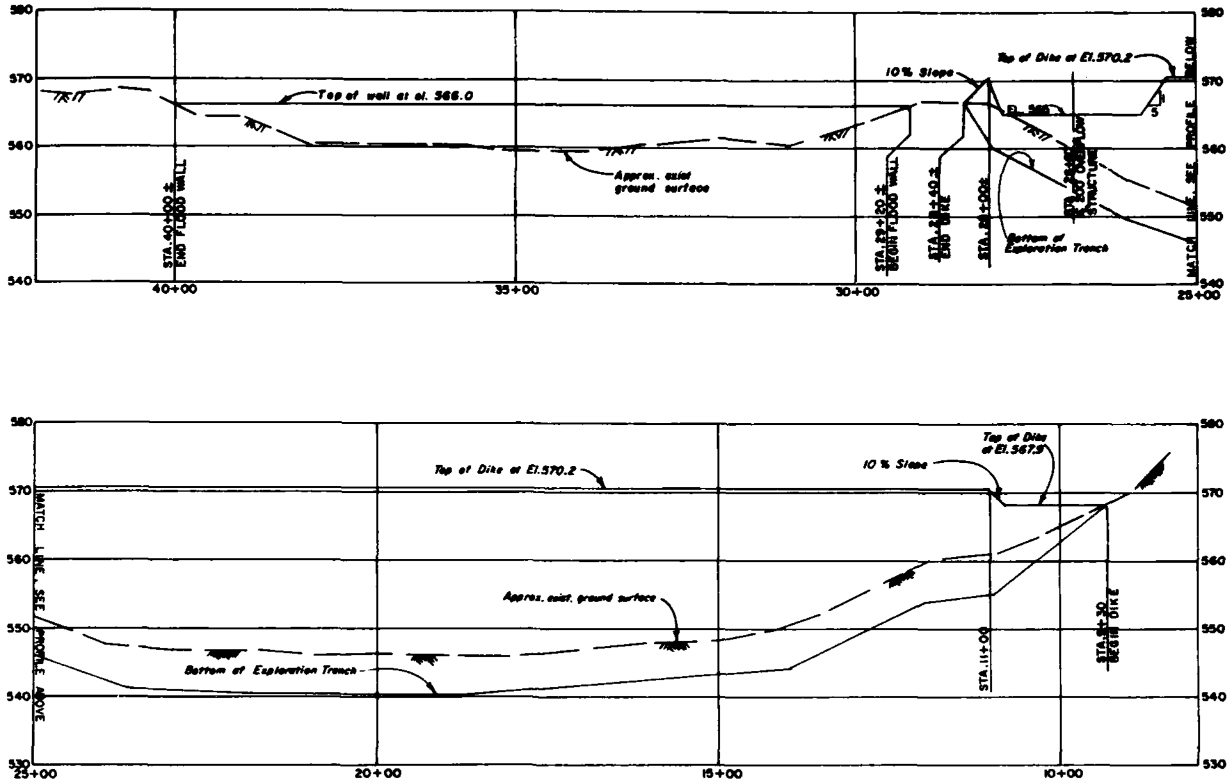
SCALE: 3/8 IN. = 1 FT.



36" CULVERT AT STA. 23+30

SCALE 1 IN. = 10 FT.

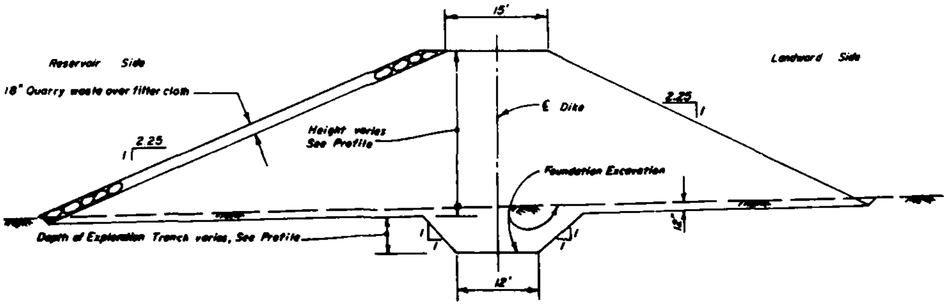




PROFILE OF FLOOD WALL AND DIKE

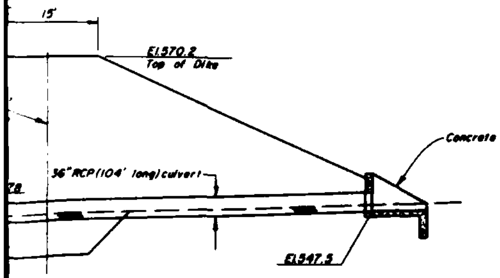
HORIZ. SCALE FEET

VERT. SCALE FEET



TYPICAL EMBANKMENT SECTION

SCALE: 1 IN. = 10 FT.



RT AT STA. 23+30

LE 1 IN. = 10 FT.

GENERAL NOTES:

1. FOR VICINITY MAP, SEE PLATE 2.
2. FOR OVERFLOW STRUCTURE DETAIL, SEE PLATE 17.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY: DC

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
DIKE AT CORONA HOUSING TRACT
PLAN AND SECTIONS

SUBMITTED BY:

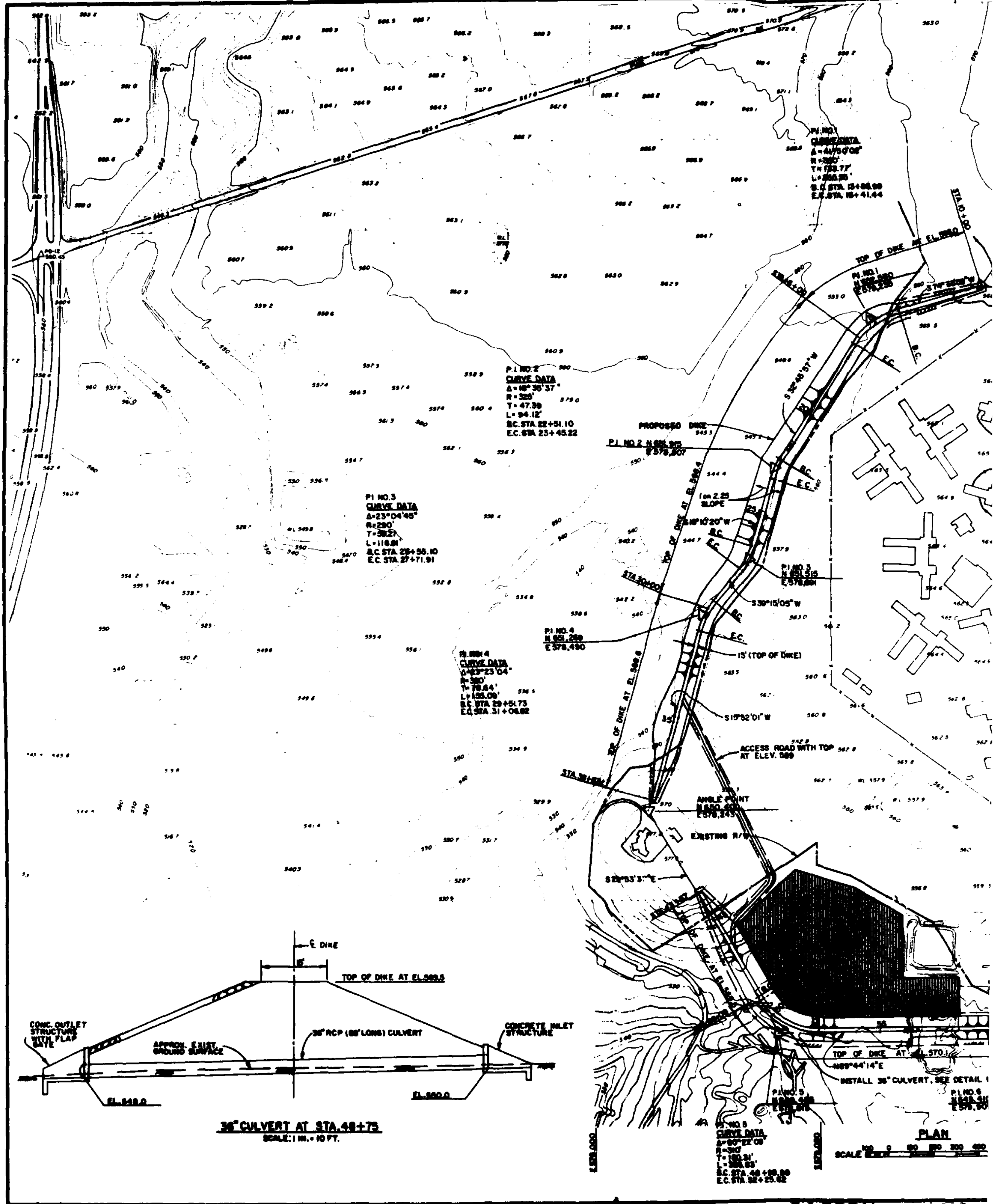
DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET 1 OF 1 SHEET

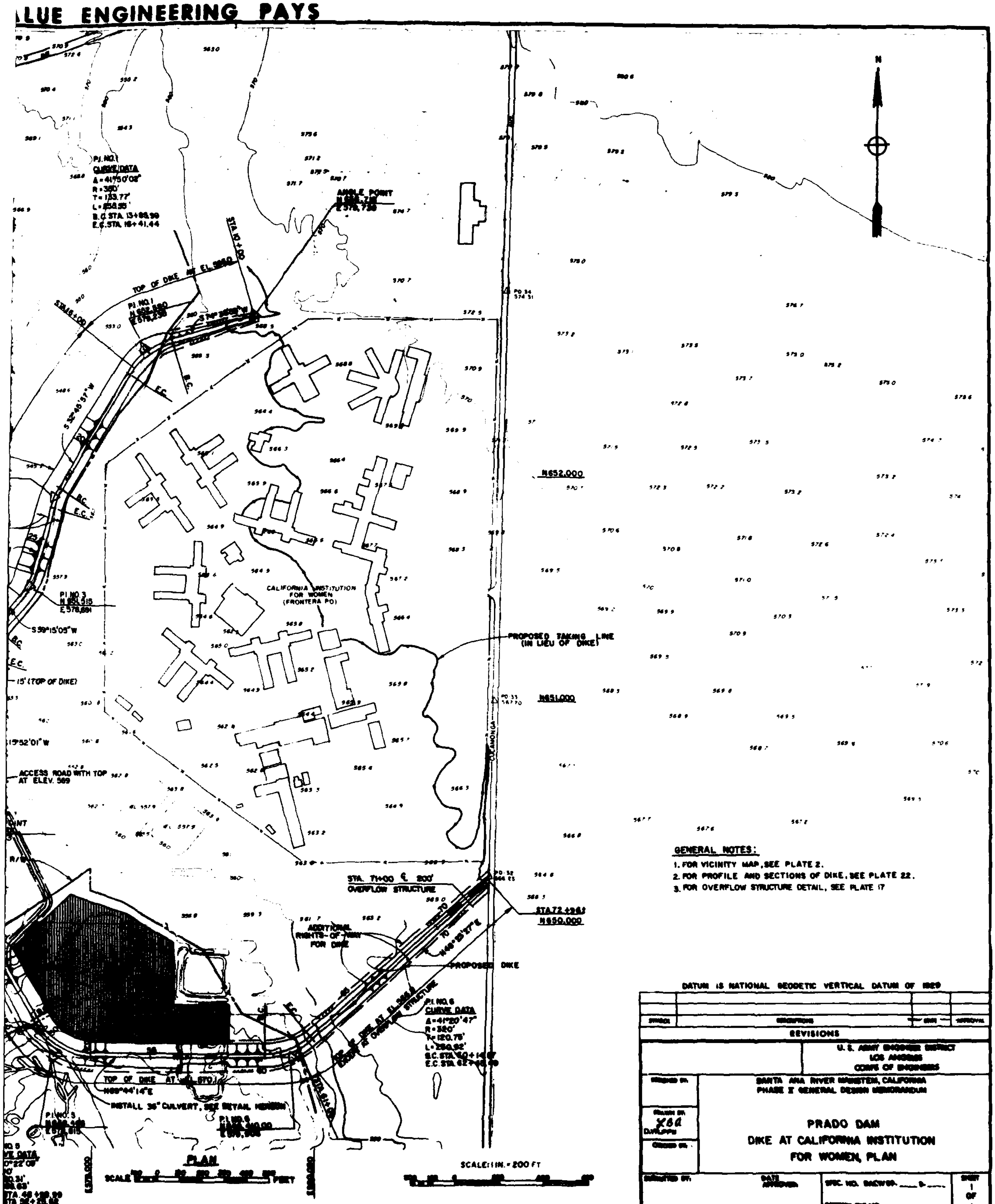
VALUE ENGINEERING P



36" CULVERT AT STA. 48+75
SCALE: 1 IN. = 10 FT.

PLAN

SAFETY PAYS



GENERAL NOTES:

1. FOR VICINITY MAP, SEE PLATE 2.
2. FOR PROFILE AND SECTIONS OF DIKE, SEE PLATE 22.
3. FOR OVERFLOW STRUCTURE DETAIL, SEE PLATE 17

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY: XBA D.PHILLIPS

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE I GENERAL DESIGN MEMORANDUM

PRADO DAM
DIKE AT CALIFORNIA INSTITUTION
FOR WOMEN, PLAN

SUBMITTED BY:

DATE APPROVED:

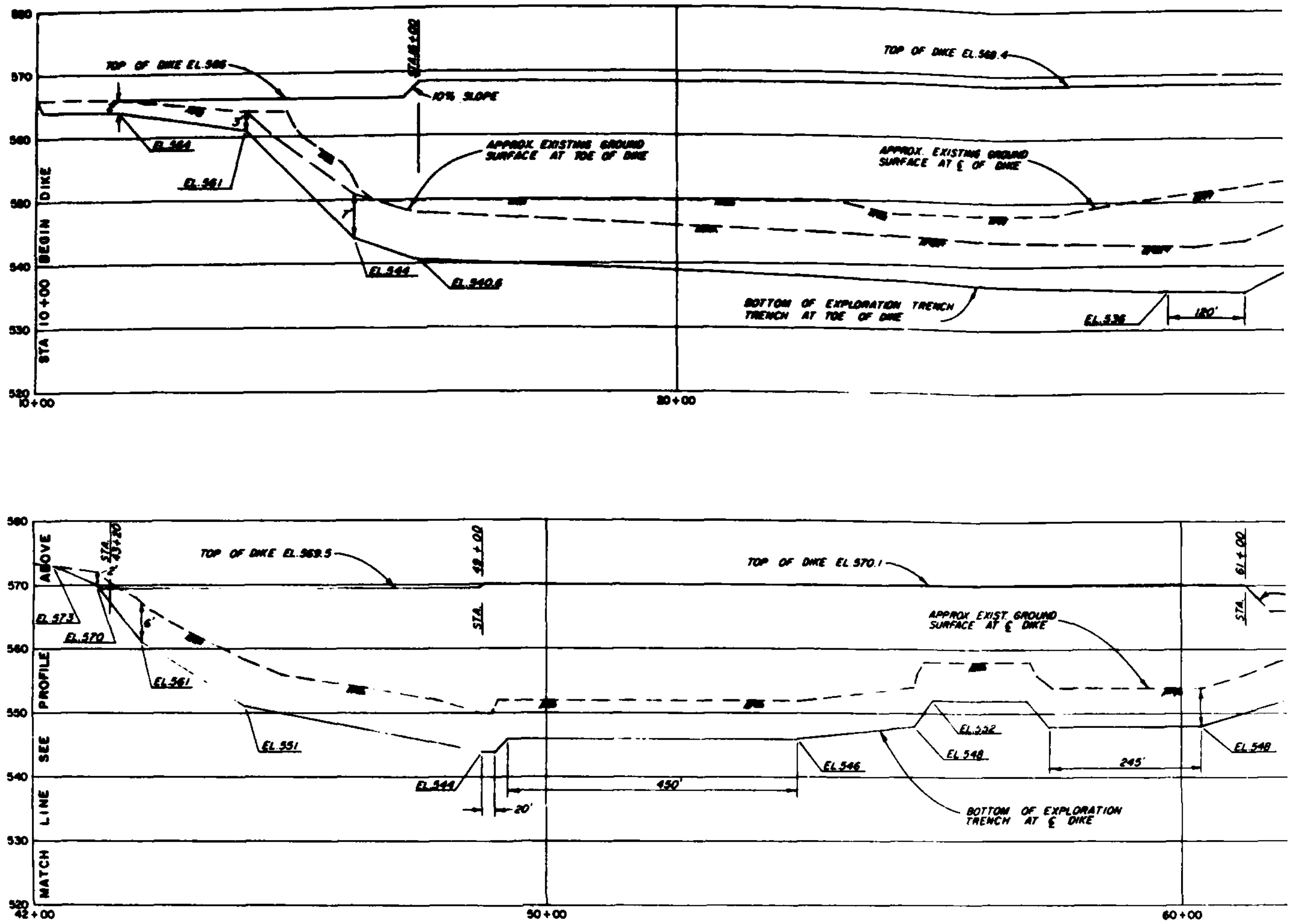
SPEC. NO. DACW09-___-B-___

DISTRICT FILE NO.

SHEET 1 OF 1 SHEET

PLATE 21

2



PROFILE

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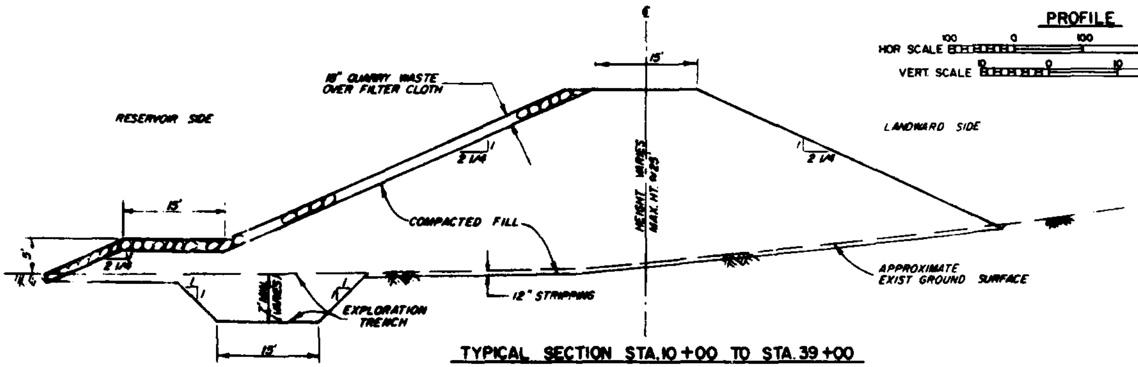
VERT SCALE 10 0 10 20 FEET



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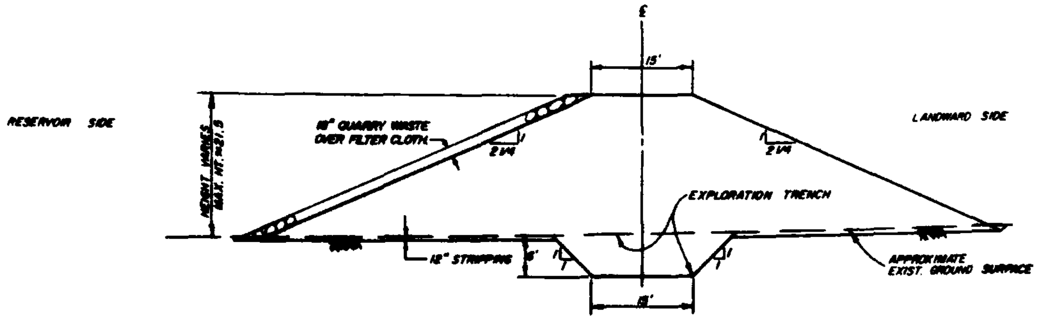

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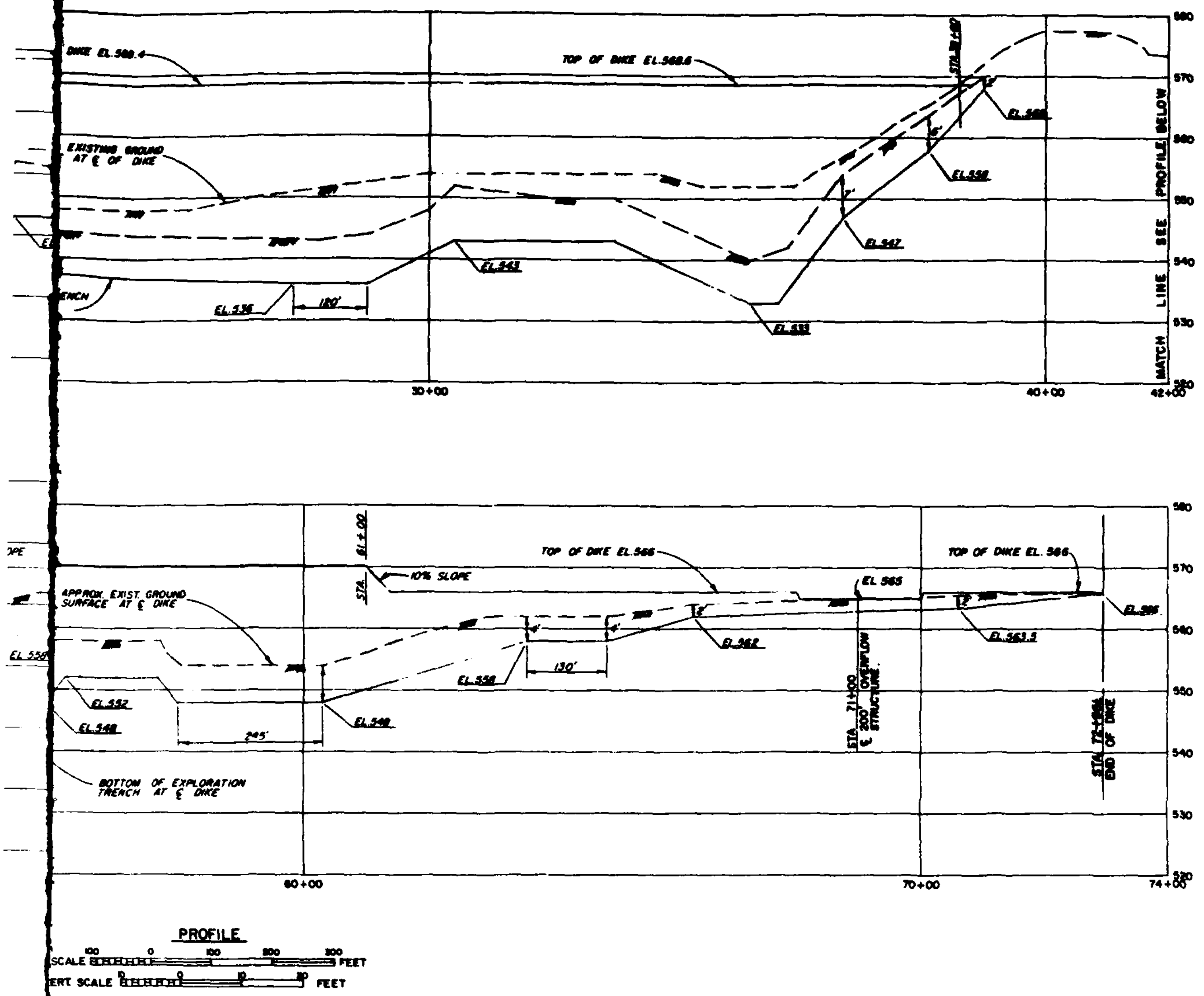
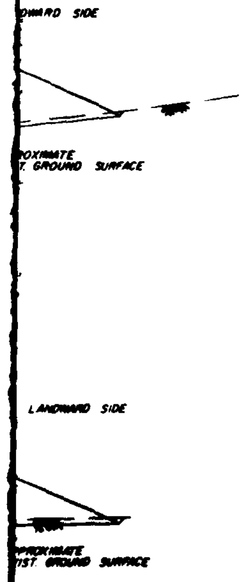




GENERAL NOTES:

1. FOR VICINITY MAP, SEE PLATE 2.
2. FOR PLAN OF DIKE, SEE PLATE 21.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:
DC

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
DIKE AT CALIFORNIA INSTITUTION
FOR WOMEN, PROFILE AND SECTIONS

SUBMITTED BY:

DATE APPROVED:

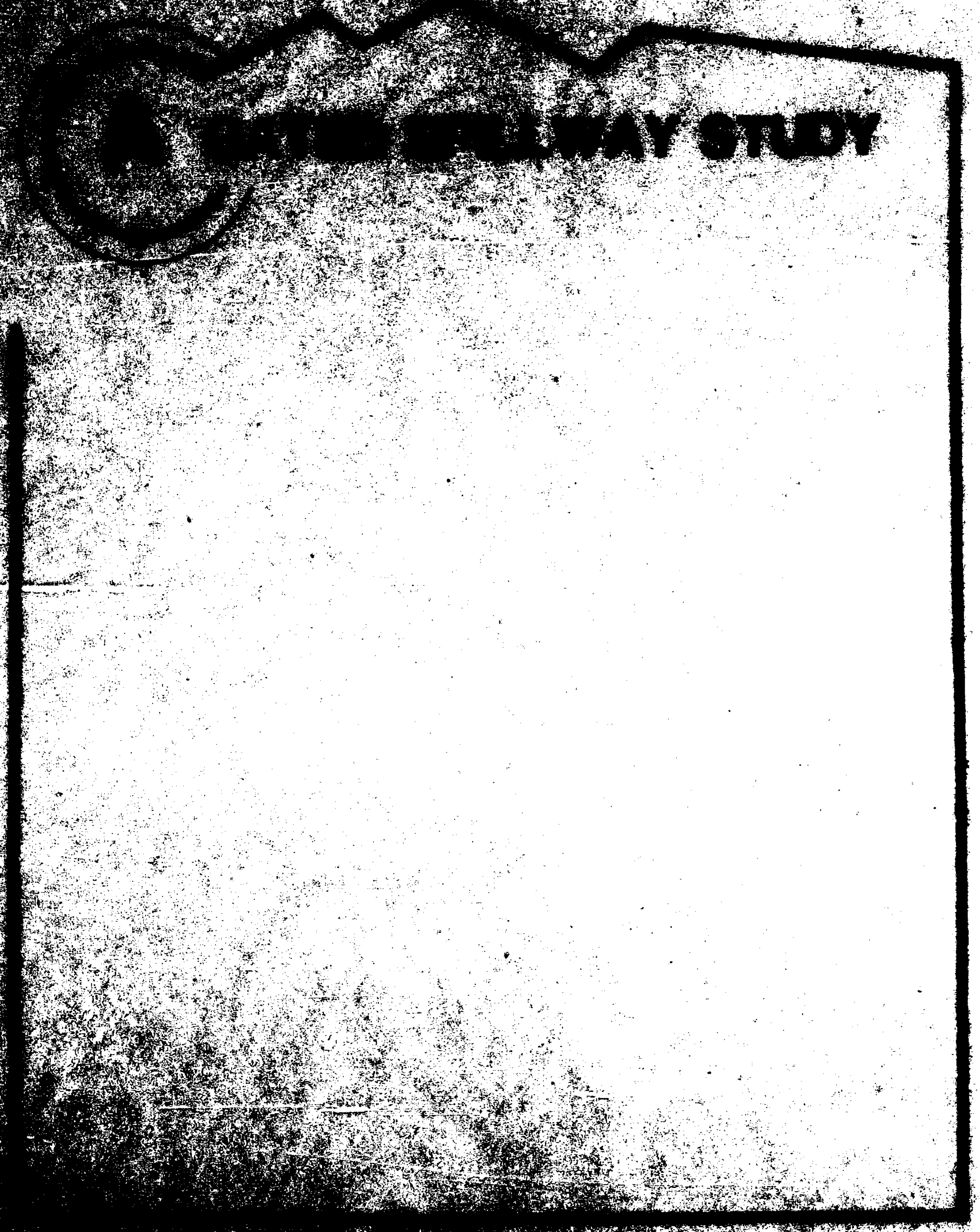
SPEC. NO. DACW09-___ B-___

DISTRICT FILE NO.

SHEET 1 OF 1 SHEET

PLATE 22

2



[illegible] SPILLWAY STUDY

CONTENTS

Tables

Contents (Continued)

Tables (Continued)

Figures

I. INTRODUCTION

1-01 Several considerations have prompted an evaluation of a gated spillway at Prado Dam as a part of the All-River Plan improvements. These include: (1) reduction in overall construction costs for proposed improvements under the All-River Plan, (2) reduction in induced flooding to upstream properties during spillway flows, and (3) reduction in length of construction time for proposed improvements. This appendix provides a comparison of gated and ungated spillway alternatives, and the reasons why the gated spillway alternative was not recommended for Prado Dam.

Consideration of Gated Spillway

GENERAL

1-02 This evaluation indicated that implementation of a gated spillway as a part of proposed dam improvements would result in approximately $40 million in cost savings over the Phase I ungated spillway. Reductions of costs and construction time for the Prado Dam improvements resulted from a reduction in construction requirements for the embankment, relocations, and outlet works.

1-03 The use of a gated spillway would lower the probable maximum floodwater surface resulting in an embankment height elevation of 582 feet. The lower embankment height would reduce the additional loading on the existing outlet to the extent that the size of the new outlet works could be reduced. The incorporation of an auxiliary outlet channel into the spillway design by using two spillway tainter gates for reservoir operation below the reservoir design flood pool could additionally eliminate the need for new outlet conduits. Also, because of the lower embankment height, Highway 71 (Corona Expressway) relocation over the elevated embankment would result in reduced relocation costs.

1-04 The hydrologic effects on upstream properties were also considered in evaluating the gated spillway. With an ungated spillway, inundation of reservoir lands during the spillway design floodflows would occur to approximately 3,800 acres of agricultural and residential properties that would not be acquired as part of the project and that are not effected by reservoir inundation under existing conditions. With a gated spillway, the acreage of reservoir land inundated during a spillway design flood, not affected under the existing condition, would be reduced to 1,050 acres.

GATED SPILLWAY

1-05 The gated spillway plan requires the construction of 25 tainter gates each having a width of 50 feet and a height of 30 feet (fig. 1). The spillway crest would be at elevation 535 feet (fig. 2). The top of the gate elevation in the fully closed position would be 565 feet, which is 1 foot below the reservoir taking line elevation of 566 feet. Selection of spillway crest elevation and tainter gate number and sizing was based on minimizing existing spillway modification costs.

EMBANKMENT

1-06 In order to provide the dam embankment with sufficient freeboard to pass the probable maximum flood, an additional 16 feet of compacted-earthfill embankment would be placed on the crest and downstream slope of the existing dam. The existing impervious zone would be removed to a point 8 feet below the top of the existing dam, and the impervious zone would be extended along a slope to elevation 582. The upstream face of the added embankment would be on a slope of 1V on 2.5H (along the same plane of the existing slope), and would be revetted with 24 inches of stone over 15 inches of bedding and filter material. The downstream face of the embankment would be on a slope of 1V on 2.5H.

SPILLWAY

1-07 The existing ogee spillway and left and right spillway walls would have to be removed entirely and a new cantilevered retaining walls constructed. The left wall would be constructed on a straight alignment, 500 feet south of the existing left wall. The new left wall would be extended westerly (downstream) just past the interchange of State Highway 71 and the Riverside Freeway. The right wall would be reconstructed along a straight alignment near the existing right wall. Ten-foot-wide piers would be constructed on 60-foot centers across the spillway to support the tainter gates. Wingwalls on both sides of the spillway would be constructed upstream of the spillway, each at a length of about 400 feet. Two tainter gates at the right side of the spillway would be 36 feet in height with an invert elevation of 529.0 feet, allowing them to be used as an auxiliary outlet in conjunction with the existing outlet works.

OUTLET WORKS

1-08 Raising the dam embankment an additional 16 feet would not require any structural changes to the existing outlet conduit. The control house, including the service bridge for the outlet works, would have to be raised an additional 16 feet.

RELOCATIONS

1-09 At the west abutment, Highway 71 would be raised to pass over the crest elevation of the new embankment. Phase I documents noted that this condition would create unacceptably high roadway grades from the top of the dam to the existing Highway 71 bridge crossing the Santa Ana River. As a result, the Phase I GDM recommended construction of a new bridge along Highway 71, 2,350 feet in length, crossing over both the east and west bound lanes of the Riverside Freeway. No increase in width or additional traffic lanes would be provided. The Highway 71 and Riverside Freeway interchange would be rebuilt incorporating the new Highway 71 bridge. Subsequent studies have shown that by locating the high point (elevation 594.9) of Highway 71 approximately 2,200 feet north of dam axis would avoid the reconstruction of the bridge for Highway 71 and its interchange with Riverside Freeway for the ungated spillway option.

II. OPERATION PLAN--GATED SPILLWAY

2-01 The spillway operation plans evaluated were based on an automatic spillway gate operation in which gate openings are solely a function of reservoir pool elevation, i.e., there is no requirement for operational decision-making by water control managers.

Operational Objectives

2-02 As outlined in the Corps of Engineers guidance for reservoir regulation (EM 1110-2-3600, para. 4.05), reservoirs controlled by gated spillways should be designed and operated insofar as practicable to accomplish the following objectives during periods when the reservoir is filled or nearly filled.

a. The peak rates of reservoir release during damaging floods should not exceed peak rates of corresponding floods that would have occurred during runoff conditions prevailing before construction of the reservoir.

b. The rate of increase in reservoir releases during a significant increment of time should be limited to values that would not constitute a major hazard to downstream interests.

c. The impacts on property within the surcharge elevation range should be considered in the selection of gated spillway operation.

Operation Plan Analysis

2-03 Reservoir routing simulation for two gate operation plans for the gated spillway configuration were made using the computer program Simulation of Flood Control and Conservation Systems (HEC-5). The simulations were examined and pool elevation and reservoir outflow were compared to the inflow hydrograph to ensure that the operational objectives for gated spillways were met. A tabular summary of alternative operating schedules and starting water surface elevations is provided below.

Operating Plan	Gate Opening Criteria (See Notes Below)		Starting Water Surface Elevation	
	Criteria 1	Criteria 2	Empty Reserv.	Full Reserv.
1a	X		X	
1b	X			X
2a		X	X	
2b		X		X

NOTES: 1. Gate opening criteria 1: Gates are kept 1 foot above the reservoir pool at all times.

2. Gate opening 2: Gate openings are less than or equal to 0.6 times the spillway pool head.

2-04 Plan 1. The gates are operated such that the top of the gates are kept 1 foot above the pool elevation at all times. This operation plan maximizes surcharge storage regardless of flood magnitude. Cases 1a and 1b represent beginning the routing with the reservoir empty and full, respectively.

2-05. Plan 2. The spillway gates are operated to release larger discharges than Plan 1 at corresponding water surface elevations, but still satisfy the gated spillway "operation objectives" as outlined above. The gated openings are less than or equal to 0.6 times the spillway pool head. This setting is required in order to maintain control and avoid free spillway overflow. Cases 2a and 2b represent beginning the routing with the reservoir empty and full, respectively.

2-06 Support information and assumptions common to the analysis of both plans are presented below.

a. The capacity-elevation relation for Prado Reservoir, based on 2-foot contour interval topographic maps developed from an August 1979 survey.

b. Future PMF hydrograph (having a peak discharge of 700,000 f^3/s) as presented in appendix C of the Phase I GDM.

c. The low level outlets are assumed inoperable and closed during spillway release conditions.

d. The spillway discharge was based on gate rating curves developed for the proposed design. The rating curves were derived using Waterways Experiment Station tainter gate discharge design charts and the HEC-2 Water Surface Profile computer program. The gate rating curves represent the spillway gates being operated in unison.

e. The difference in operation and maintenance costs between gated and ungated spillway was assumed to be small; therefore was not included in the analysis.

f. Reservoir taking line will be at elevation 566 feet for both gated and ungated spillway, and environmental impacts of both spillway alternatives were assummed to be identical.

Operational Plan Results

2-07 The results of the operational plans are summarized in table 1. The inflow hydrograph, reservoir water level and outflow hydrograph are graphically illustrated for various cases in figures 3, 4, and 5.

2-08 Figure 3 compares the Phase I GDM and Plan 1 reservoir routings. Figures 4 and 5 compares Plan 1 to Plan 2 for the empty and full reservoir starting conditions. From analysis of table 1 and figures 4 and 5, both Plans 1 and 2 meet the rate of change in outflow objectives.

2-9 The starting pool elevation and the low level outlet releases (if operable) were found to have a negligible effect on the maximum pool level reached for the gated spillway operation plans.

2-10 Results of the two operational plans lead to the following conclusions.

a. The gated spillway would be capable of passing the peak inflow of the PMF hydrograph, hence, alleviating any hydrologic concerns with respect to dam safety.

b. Plan 1 achieves all operational objectives for both reservoir starting conditions, however, it does induce substantial surcharge storage above the reservoir taking line.

c. Plan 2 achieves all operational objectives for both reservoir starting conditions and at the same time minimizes surcharge storage requirements and hence maximum surcharge water surface elevations.

d. For corresponding water surface elevations Plan 2 provides a greater release capability than Plan 1.

Table A-1. HEC-5 Results for Gated Spillway Operation.

Gate Operation	Phase I GDM (Ungated)	Plan 1 (Gates are kept 1 foot above the pool at all times)		Plan 2 (Gate openings less than or equal to 0.6 the the spillway pool head)	
Case		1a (Empty Reservoir)	1b (Full Reservoir)	2a (Empty Reservoir)	2b (Full Reservoir)
Starting Pool El. (ft)	545.3	510	563	510	563
Outlet Discharge (cfs)	30,000	0	0	0	0
Maximum Pool Elevation (ft)	584.9	579.1	579.2	574.6	574.6
Top of Dam Elevation (ft)	596.0	586.1	586.2	581.6	581.6
Maximum Increase Discharge (cfs/hr)	50,000	68,000 at outflow of 54,000 to 122,000.	53,000 at outflow of 561,000 to 614,000.	80,000 at outflow of 236,000 to 316,000.	55,000 at outflow of 480,000 to 533,000.
Maximum Discharge (cfs)	605,000	660,000	665,000	667,000	669,000

III. COMPARISON OF DETAILED PLANS

Hydrologic Effects

3-01 An analysis of upstream and downstream hydrologic effects was conducted for gated and ungated spillway alternatives. Of the two alternatives, a gated spillway maximum reservoir water surface elevation would be most comparable to the existing project (prior to Santa Ana River All-River Plan improvements) maximum reservoir pool condition. However, spillway discharges at given flood frequencies were found to be greater than the ungated spillway alternative. With the ungated spillway the maximum reservoir water surface was found to be significantly higher than the existing project or gated spillway condition.

Upstream Effects

3-02 With a gated spillway the maximum reservoir water surface would reach elevation 574.6 feet. This would be greater than the maximum reservoir water surface that would occur under existing conditions without dam failure (elevation 570.4 feet). Construction of Prado Dam improvements using an ungated spillway and the recommended outlet operation plan would result in a maximum water surface elevation under PMF conditions of 584.9 feet. Maximum rate of rise of the water surface under either alternative would be about 1 foot per hour. A summary of relevant reservoir pool data for both conditions is shown in table 2.

Downstream Effects

3-03 The gated spillway operating plan would result in higher flood discharges for given flood frequencies than would occur with an ungated spillway. For the gated spillway, higher discharges are required to maintain the reservoir water surface at or near the existing project maximum water surface elevation.

Table A-2. Relevant Reservoir Pool Data for Gated and Ungated Spillways.

Condition	Maximum Water Surface Elevation (m.s.l.)	Area Inundated[a] (acres)
Existing condition (without dam failure)	570.4[b]	12,200
Existing conditions (with DSAP modifications)	574.5	13,200
With All-River Plan (Gated Spillway)	574.6	13,250
With All-River Plan (Ungated Spillway)	584.9	16,000

NOTES: a. Based on area-capacity relationships presented in the Review of Design Features of Existing Dams, April 1972.
b. Top of existing dam is elevation 566 feet; overtopping of entire length of dam embankment is assumed during a PMF.

Economic Effects

3-04 Comparative first cost of the gated and ungated spillway alternatives has been performed. In addition, a benefit-cost evaluation of the gated spillway has been conducted. Results of the evaluation are provided in the following paragraphs.

Capital Cost

3-05 Cost analysis indicates that the gated spillway alternative would be approximately $39,300,000 less costly than the ungated spillway. Cost analysis are considered very preliminary in nature since values are escalated from earlier cost estimates, based on quantities and unit costs, dating to September 1979. Cost savings would result mainly from the elimination or reduced need for a new outlet works, less embankment construction, the ability to salvage the existing outlet, and reduced relocation requirements for Highway 71.

Benefit-Cost Analysis

3-06 Benefit-Cost analysis was performed for the All-River Plan incorporating both gated and ungated spillway alternatives at Prado Dam. The analysis was performed using economic data presented in the

Santa Ana River Mainstem Phase I GDM Supplement, dated December 1985 and discharge-frequency relationships presented in table 3. Annual costs for the gated and ungated spillway alternatives at Prado Dam are based on preliminary cost data presented in table 4.

Table A-3. Elevation and Discharge-Frequency Data for Gated and Ungated Spillway at Prado Dam With All River Plan Improvements.

Spillway Condition	Flood Condition	Prado Max WSEL	Prado Outflow cfs	Imperial Hwy. cfs	First St. Santa Ana cfs
Present Ungated	SPF	561.5	30,000	32,000	38,000
Present Gated	SPF	561.5	30,000	32,000	38,000
Future Ungated	SPF	566.8	43,000	45,000	53,000
Future Gated	SPF	565.0	43,000	45,000	53,000
Present Ungated	500-yr	570.7	95,000	92,000	85,000
Present Gated	500-yr	566.5	136,000	132,000	122,000
Future Ungated	500-yr	573.1	180,000	176,000	163,000
Future Gated	500-yr	569.1	286,000	279,000	257,000
Present Ungated	1,000-yr	573.8	198,000	192,000	172,000
Present Gated	1,000-yr	567.0	280,000	273,000	251,000
Future Ungated	1,000-yr	576.8	280,000	273,000	251,000
Future Gated	1,000-yr	570.1	352,000	342,000	320,000
Present Ungated	PMF	583.8	542,000	532,000	500,000
Present Gated	PMF	574.2	634,000	624,000	584,000
Future Ungated	PMF	584.9	605,000	595,000	555,000
Future Gated	PMF	574.6	667,000	657,000	617,000

NOTE: Top of existing dam is elevation 566 feet; overtopping of entire length of dam embankment is assumed during a PMF.

Table A-4. Comparison of Costs for Gated and Ungated Spillways.[a]
(Costs in $1000's)

Items	Gated Spillway (Raise Dam 16 ft.)	Ungated Spillway (Raise Dam 30 ft.)
Diversion & Control of Water	$335	$335
Clear & Remove Obstructions	290	290
Main Embankment	5,674	22,978
Spillway		
Gated	86,256	
Ungated		50,493
Outlet Works		
New Outlet Works		
Modify Exist. Outlet	5,000[b]	44,956
Auxiliary Dike	1,730	2,991
Highway Relocation	5,567	9,700
Beautification	3,000	3,000
Utilities	1,441	1,441
Subtotal	$109,293	$136,184
Contingency (25%)	27,323	34,046
Engineering & Design and Supervision & Administration (17%)	23,224	28,939
TOTAL CONSTRUCTION COST	$159,840	$199,169

NOTES: a. Cost estimates were derived by escalating to current price levels cost data presented in the following reports.

1. Santa Ana River Phase I GDM, dated September 1980.
2. Prado Dam Alternative Study for Major Rehabilitation, July 1985.
3. Prado Dam Design and Cost Estimate, Gated Spillway, September 1983.
4. Prado Dam Design Memorandum for Major Rehabilitation, July 1985.

b. Includes cost of auxiliary outlet channel downstream of proposed spillway improvements.

3-07 Table 5 presents annual benefits of Prado Dam, assuming all other elements of All-River Plan are in place. It should be noted that the relatively large increase in damages with the gated spillway results from the large increase in discharges from the dam for given flood frequencies. For example, the gated spillway increases flows over the ungated spillway condition at the 500-year flood frequency approximately 40 percent and at the 1,000-year flood event frequency by approximately 50 percent. Benefits were calculated at 8-7/8 percent interest rate over a 100-year economic project life.

Table A-5. Comparison of Annual Benefits for Gated and Ungated Spillways. (Benefits in $1,000's)

All-River Plan		Net Effect of Implementing Ungated Spillway
With Gated Spillway	With Ungated Spillway	
$105,449	$120,176	(+)$14,727

3-08 Table 6 presents an incremental analysis of the effects of investing approximately an additional $40 million in first cost to construct an ungated structure. The incremental annual cost of $4,577,000 includes additional interest during construction resulting from additional construction period anticipated with construction of an ungated spillway. The increased annual benefit is $14,727,000. The separable feature of an ungated spillway over a gated spillway has a benefit-cost ratio of 3.2 to 1.

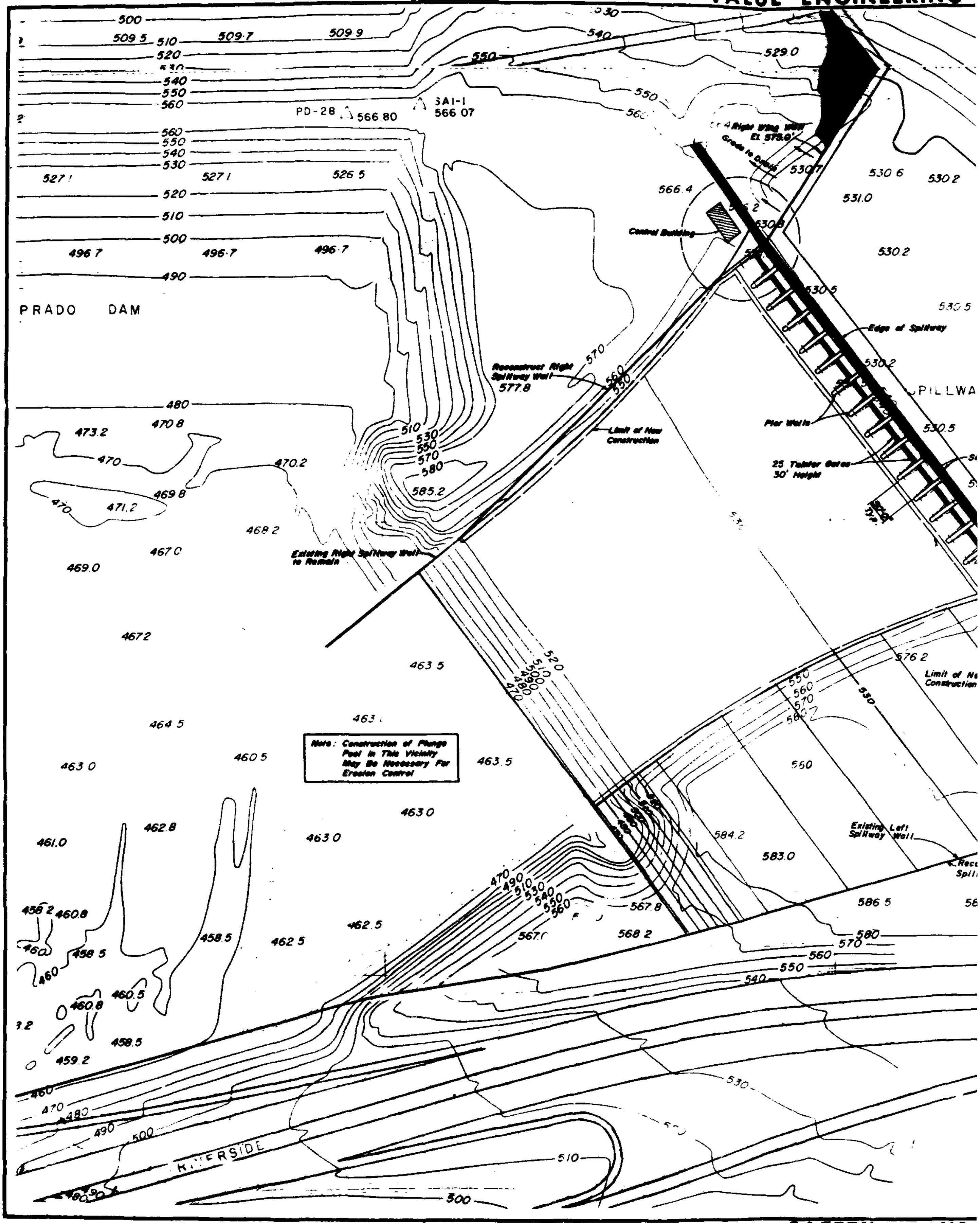
Table A-6. Incremental Analysis of Annual Costs and Benefits for Ungated Spillway. (In thousands of dollars)

	Increment Benefits	Increased Costs	Incremental B/C	Net Benefits
Annual incremental values in modifying from gated to ungated spillway.	$14,727	$ 4,577	3.2	$10,150

IV. SUMMARY AND RECOMMENDATION

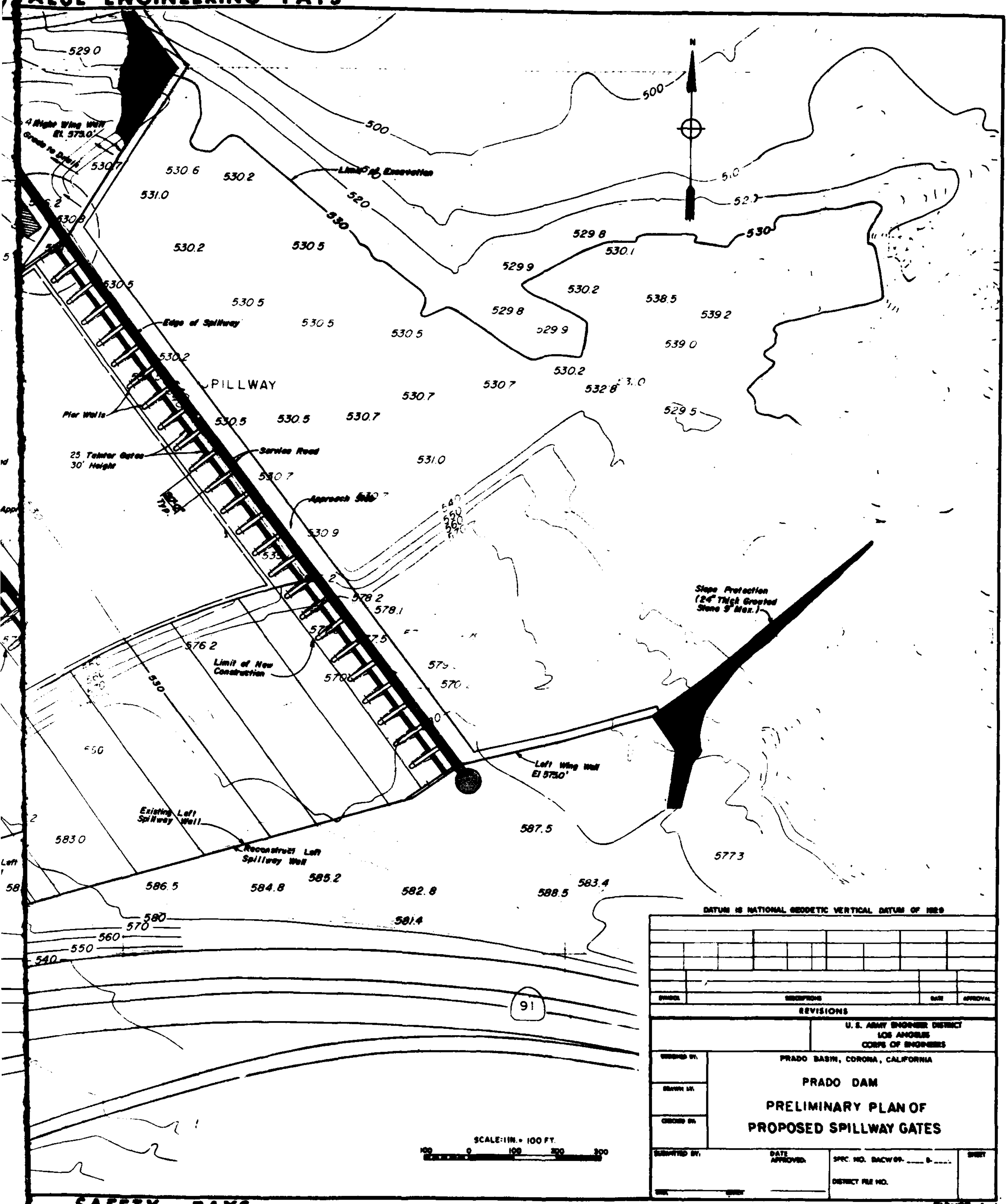
4-01 Employing a gated spillway at Prado Dam results in significant cost savings to the project (approximately $40 million) over the ungated spillway option, minimizes induced flooding to upstream properties, and reduces construction time for Prado Dam improvements. However, benefit-cost analysis discloses that approximately $3.20 in benefits would be lost for each $1.00 saved.

4-02 Subsequent to the study, cost reductions were realized to the ungated spillway mainly by reduction in spillway width from 1,400 feet to 1,000 feet. In addition Highway 71 relocation costs as presented in the Phase I plan were reduced. These findings would make the overall cost savings related to the gated spillway less substantial than this study paper indicated and hence less attractive as an alternative. As a result, the gated spillway alternative was found to be economically unjustified and the ungated spillway is recommended for implementation.



Note: Construction of Plunge Pool In This Vicinity May Be Necessary For Erosion Control

VALUE ENGINEERING PAYS



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

PRADO BASIN, CORONA, CALIFORNIA

PRADO DAM

PRELIMINARY PLAN OF
PROPOSED SPILLWAY GATES

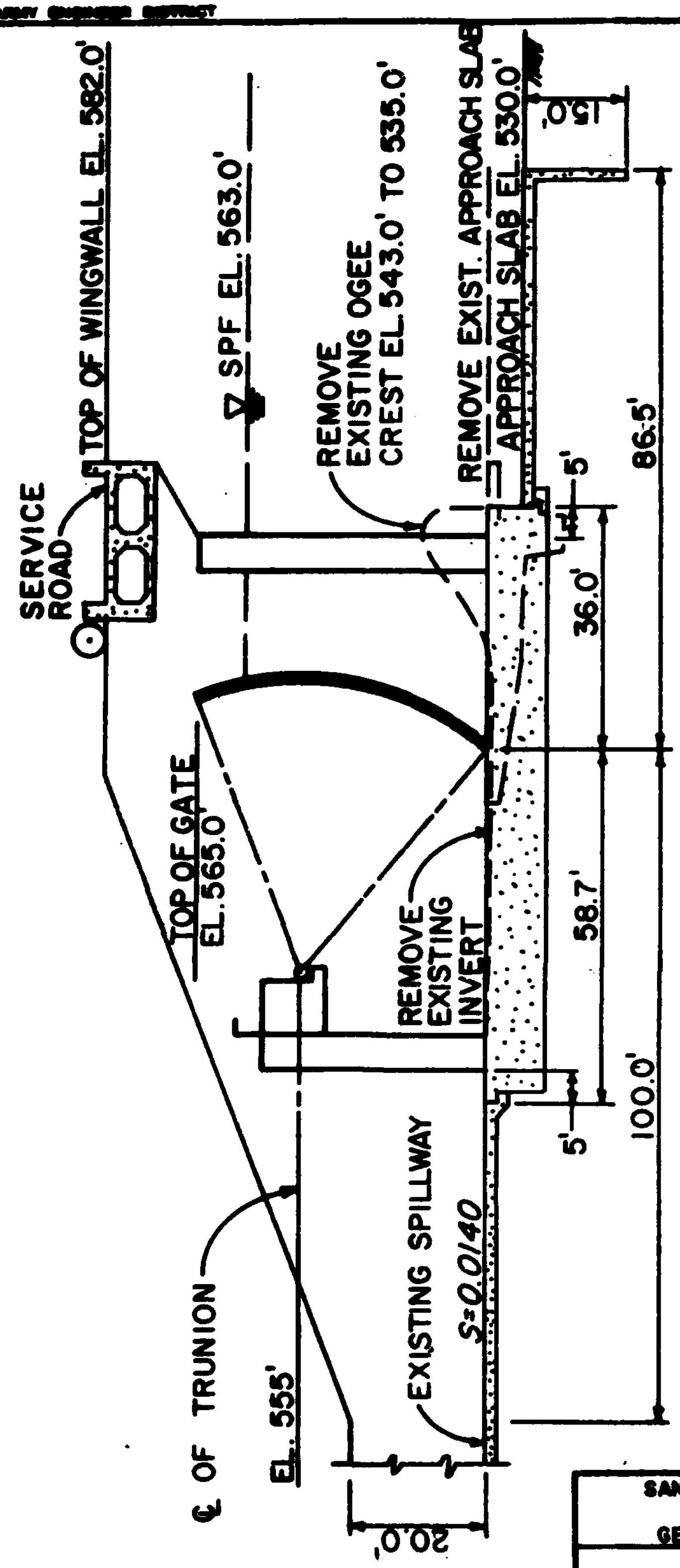
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

FIGURE A-1

SAFETY PAYS

1

2



TYPICAL SECTION OF PROPOSED SPILLWAY GATES

NOT TO SCALE

SANTA ANA RIVER MAINSTEM, CA.
PHASE II
GENERAL DESIGN MEMORANDUM

PRADO DAM

TYPICAL SECTION
OF PROPOSED SPILLWAY GATES

U.S. ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

FIGURE A-2

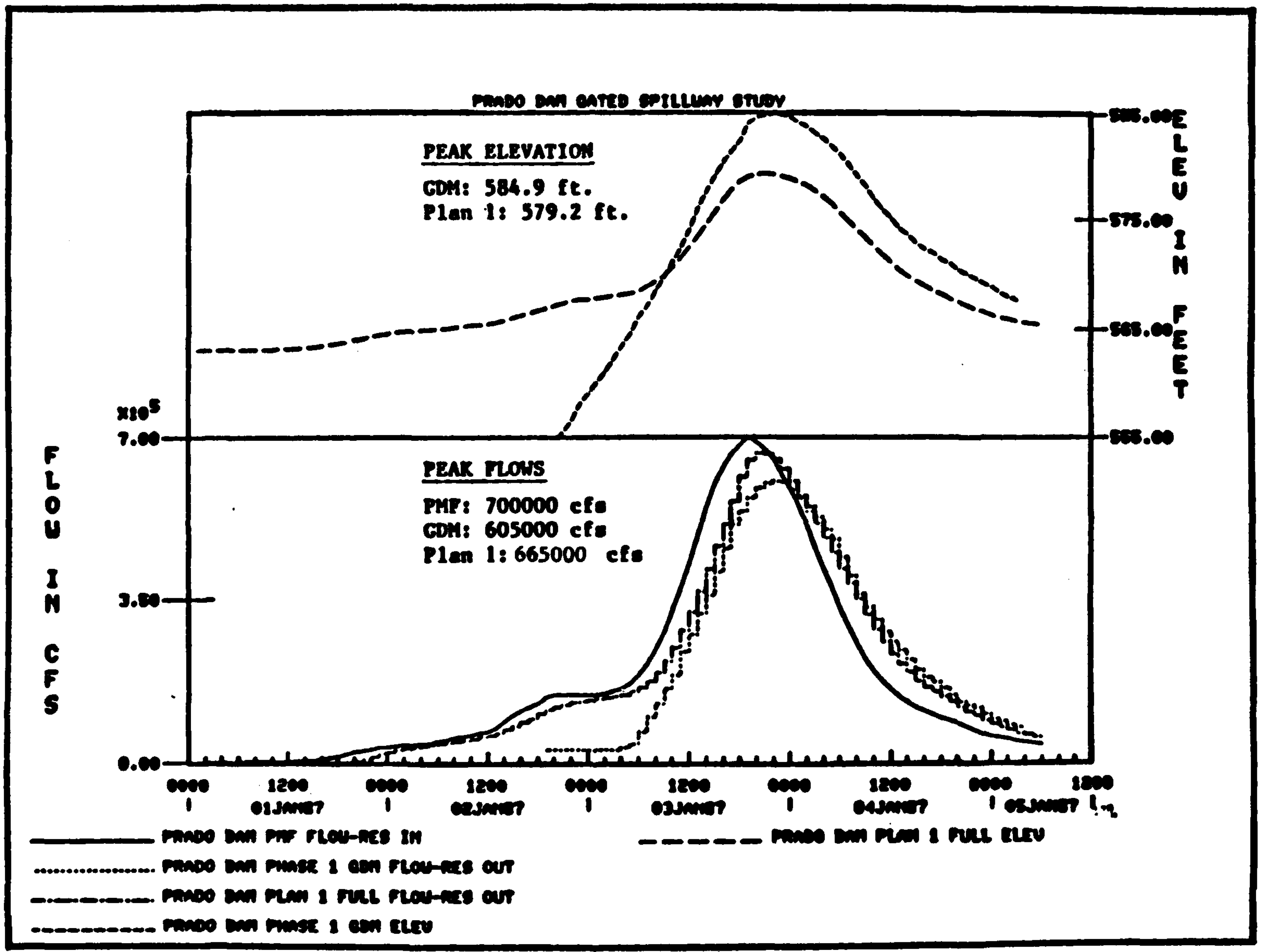
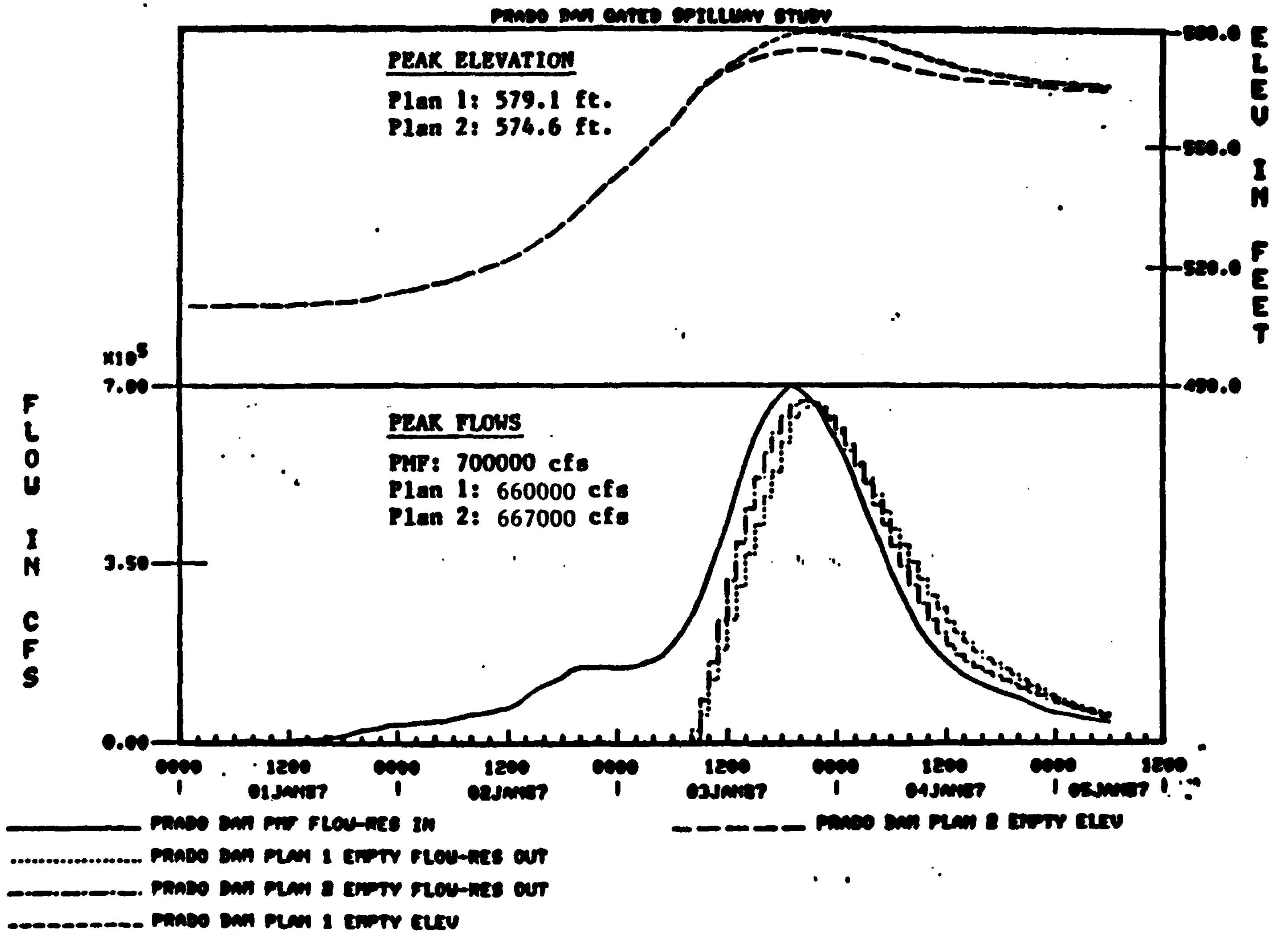


FIGURE A-3

Comparison of the PMF reservoir routings for the Phase 1 GDM spillway design and Plan 1.



Comparison of Plan 1 and 2 PMF reservoir routings (Case A: reservoir starting empty).

FIGURE A-4

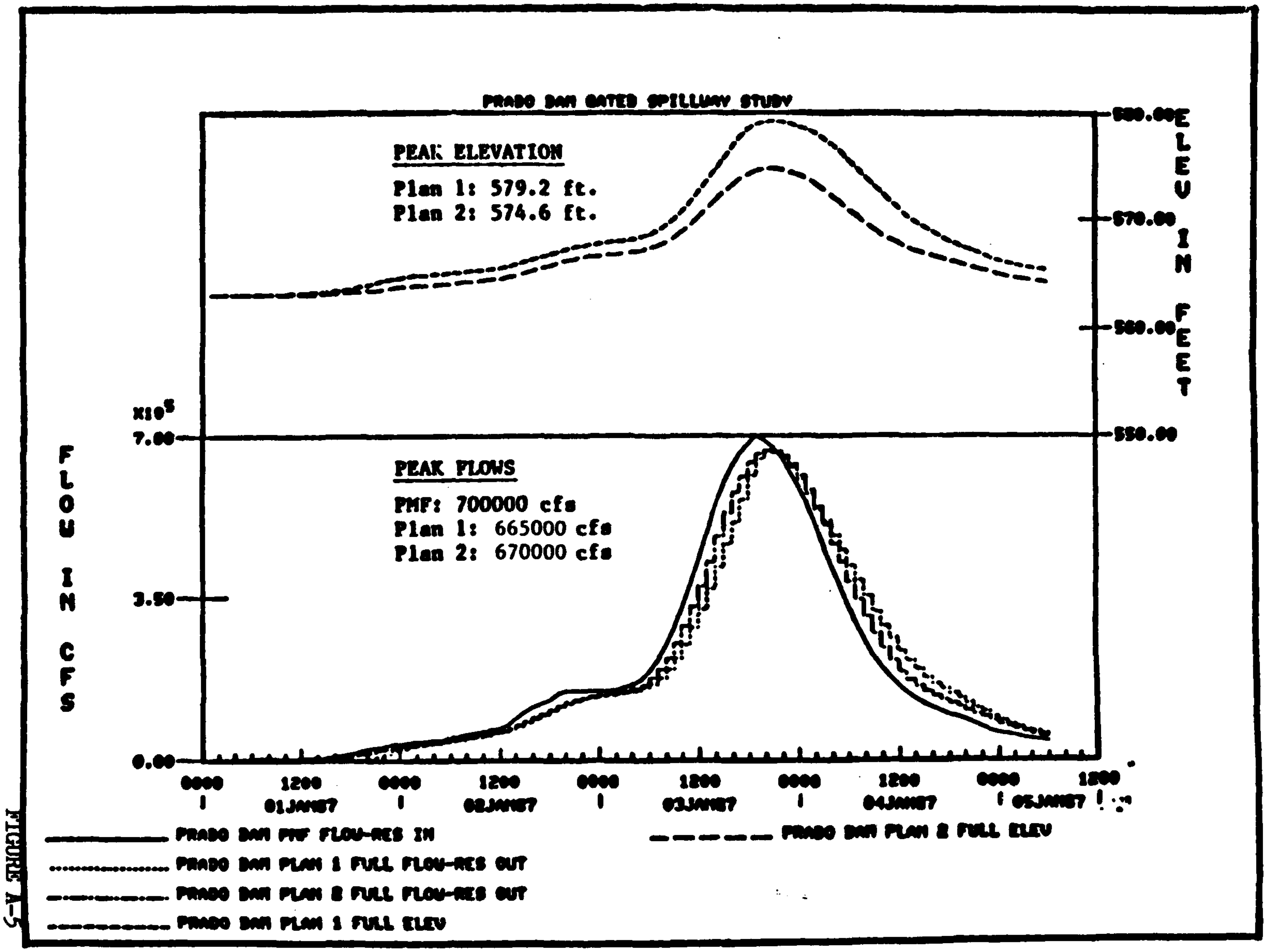


FIGURE A-5

Comparison of Plan 1 and 2 PMF reservoir routings (Case B: reservoir starting full).

B

GEOTECHNICAL

PRADO DAM

PHASE II GENERAL DESIGN MEMORANDUM

APPENDIX B

GEOTECHNICAL APPENDIX

U.S. ARMY ENGINEER DISTRICT,
LOS ANGELES
CORPS OF ENGINEERS

AUGUST 1988

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I. INTRODUCTION

Purpose and Scope

1-01 Geotechnical investigations were conducted to analyze, evaluate, and design the proposed modifications to the Prado Dam embankment and reservoir. Investigations were conducted to provide a technical basis for the phase II design. This appendix summarizes design, construction, and post-construction studies and documents field investigations. It describes the geology, groundwater, faulting and seismicity, foundation conditions, existing embankment and construction data, methods of analyses, design and construction procedures. This appendix summarizes laboratory test results. Descriptions of procedures, conditions, equipment used, and detailed laboratory test results are on file and available at the Los Angeles District Geotechnical Branch.

1-02 The phase II investigations of the outlet works, auxiliary dike, and dikes at the Corona Sewage Treatment Plant, California Institution for Women, Alcoa Aluminum Plant, Corona National Housing Tract, and Corona Expressway were limited to reducing uncertainties about the site conditions and construction materials that would significantly impact the feasibility and cost of the project. Additional studies have been identified to verify conservative designs and will be performed during preparation of plans and specifications and for the Outlet Works Feature Design Memorandum.

Description of Project

1-03 For a complete description of the project see the main report of volume 2. The proposed project plan requires enlarging Prado Dam and reservoir to control the design flood. The main features of the proposed plan for Prado Dam and reservoir area are as follows and are presented on plate B-1:

a. Raise the existing Prado Dam embankment crest a maximum height of 28.4 feet from elevation 566 to 594.4 feet, NGVD (National Geodetic Vertical Datum of 1929). This would be accomplished by first removing the top 8 feet of the embankment and the 12 inches of gravel on its downstream slope. Compacted fill would then be placed on the scarified surface. The upstream slope revetment for the modification would consist of 24 inches of stone over 9 inches of bedding material over 6 inches of filter material (or filter cloth). The typical section of the dam is shown on plate B-14.

b. Construct a new outlet works through the left abutment between the existing dam embankment and spillway. The new outlet works alinement is presented on plates 8 and 9 of the main report, volume 2.

c. Modify the existing spillway and construct training dikes. The dikes would extend 300 feet upstream from the spillway crest. They would be earthfill structures with side slopes of 1V on 2H and the top width would be 16 feet. The side slopes would be protected with 18 inches of grouted stone. See plate 4 of the main report, volume 2 for a typical section.

d. Construct an auxiliary dike on the south side of the proposed reservoir approximately along the Santa Fe Railroad. The auxiliary dike would be a compacted earthfill structure. The embankment would have a crest length of approximately 5370 feet and a top width of 20 feet. The top elevation would be at 594.4 feet and the maximum height above the existing ground would be 74 feet with an average height of 30 feet. The upstream and downstream side slopes would be 1V on 2.25H. The upstream slope revetment would consist of 24 inches of stone over 9 inches of bedding material over 6 inches of filter material (or filter cloth). An exploration trench would be located along the centerline of the embankment and would vary in depth from 4 to 10 feet with a base width of 15 feet and side slopes of 1V on 1H. A typical cross section is presented on plate B-15.

e. Construct ring dikes to protect the Corona Sewage Treatment Plant, the Alcoa Aluminum Plant, the California Institution for Women, and the Corona National Housing Tract. All the dikes would be compacted earthfill structures with side slopes of 1V on 2.25H. Upstream slope protection would consist of 18 inches of quarry waste over a filter fabric and the downstream would be landscaped with native grass. The dike at the Corona Sewage Treatment Plant would have a crest length of approximately 3810 feet and the top elevation would vary between 566.0 and 569.8 feet. The crest would be 15 feet wide and its maximum height above the existing ground surface would be 53 feet. A 6-foot deep exploration trench would be excavated along the centerline of the embankment with a base width of 15 feet and side slopes of 1V on 1H. The dike at the Alcoa Aluminum Plant would have a

crest length of approximately 6050 feet and the top elevation would vary between 566.0 and 569.8 feet. The crest would be 15-feet wide and its maximum height above the existing ground surface would be 30 feet. A 6-foot deep exploration trench would be excavated along the centerline of the embankment with a base width of 15 feet and sides slopes of 1V on 1H. The dike at the California Institution for Women would have a total crest length of approximately 5770 feet and the top elevation would vary between 566 and 570.1 feet. The crest would be 15-feet wide and the maximum height above the existing ground surface would be 25 feet. A 7-foot deep exploration trench would be excavated beneath the upstream toe of the dike with a base width of 15 feet and side slopes of 1V on 1H. The dike at the Corona National Housing Tract would be about 1870 feet long with a top elevation varying between 567.9 and 570.2 feet. The crest would be 15-feet wide and its maximum height above the existing ground surface would be 24 feet. A 6-foot deep exploration trench would be excavated along the centerline of the embankment with a base width of 15 feet and sides slopes of 1V on 1H. The typical sections are presented on plates B-15 and B-16.

f. Modify the existing Corona Expressway. The Corona Expressway modification would be completed in three stages. The first stage would consist of constructing the lower portion of the dike to an elevation which could be utilized for detour of vehicular traffic during modification of the highway. The second stage would involve raising the highway. The last stage of construction would add the upper portion of the dike between the top of the detour to elevation 594.9 feet. The dike would be approximately 2130 feet in length with reservoir protection consisting of 24 inches of stone over 9 inches of bedding material over 6 inches of filter material (or filter cloth). The embankment would a homogeneous compacted earthfill section with sides slopes of 1V on 2H and a top width of 15 feet. Typical cross sections are presented on plate B-17.

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ON THE SANTA ANA R..(U) ARMY ENGINEER DISTRICT LOS
ANGELES CA AUG 88

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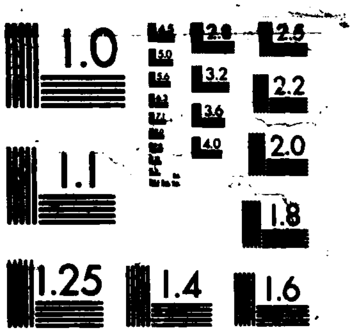

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II. GEOLOGY

General

2-01 Most of the basic geologic information on Prado Dam was obtained from various published sources. The Corps first conducted field investigations in the late 1930's for the design of the dam, in 1971 for the possible spillway modification, in 1972, 1974, and 1975 for seismic evaluation of the dam and its foundation, in 1980 to study local faulting, and in 1982, 1983 and again in 1987 for the outlet works relocation. These investigations consisted of: (1) mapping the various geologic formations, and (2) exploring the subsurface to determine the nature and extent of the soil and bedrock materials and the character of local faults. In addition, a seismicity study was conducted in 1981 to select seismic parameters to be used in the dynamic analysis of Prado Dam. A simplified map of the regional geology is presented on plate B-2. The general geology of the Prado Dam project area is shown on plate B-3 while the detailed Prado Dam site geology mapped by Woodward-Clyde Consultants (1980) is presented on plates B-4 through B-7.

Topography

2-02 Prado Dam is situated at the southwestern edge of the Upper Santa Ana Valley, a broad inland alluvial plain which is part of the larger South Coastal Basin of southern California (California Division of Water Resources, 1934), see figure B-1. This physiographic and structural basin is bounded on the north and northeast by the high and rugged San Gabriel and San Bernardino Mountains; on the south by the low, highly eroded San Timoteo Badlands, a series of granitic hills, and a low bedrock plateau; and on the west and southwest by the rolling topography of the Chino Hills and the moderately high and less precipitous Santa Ana Mountains. Elevations in the Upper Santa Ana Valley range from about 470 feet at Prado Dam to over 11,000 feet in the San Bernardino Mountains. Locally, Prado Dam is bounded by the Chino Hills and the foothills of the Santa Ana Mountains to the west and south, respectively.

The relatively flat Prado Flood Control Basin lies to the north and east of the dam. Beyond the reservoir area lie low alluvial terraces, which are also present in an extensive area adjacent to the spillway. The Santa Ana River is the principal stream of the Upper Santa Ana Valley. It rises in the San Bernardino Mountains, flows southwesterly across the generally smooth and regular valley floor to Prado Dam, through the narrow Santa Ana Canyon downstream of the dam, and across the Los Angeles Basin to the Pacific Ocean. The Santa Ana River is a perennial stream from the vicinity of Riverside to Prado Dam and generally intermittent upstream and downstream of this reach.

Regional Geology

2-03 The regional geologic setting of the Prado Dam area is marked by northwest trending structures of the Peninsular Ranges abutting the Transverse Ranges to the north. The Transverse Ranges, which include the San Gabriel and San Bernardino Mountains, contribute to the north-south compressional regime dominating the tectonics of southern California. Major faults in the area are primarily northwest trending right-lateral strike-slip faults, such as the San Andreas, San Jacinto, Newport-Inglewood, and Whittier-Elsinore fault zones. These faults separate parallel elongate structural features, such as the Puente Hills, Santa Ana Mountains and the Perris and San Bernardino blocks. In addition to the major strike-slip faults, a system of thrust faults exists at the base of the Transverse Ranges, north of the dam. Collectively, these faults are commonly referred to as the Sierra Madre/ Cucamonga Fault System.

Local Geology

2-04 Prado Dam is located at the eastern tip of the Chino Hills (also known as the Eastern Puente Hills) at the head of Santa Ana Canyon. These hills are composed of Tertiary-age (Eocene to Pliocene) sedimentary rocks (designated Ts on plate B-3) which overlie a basement complex consisting chiefly of granodioritic and associated plutonic rocks of the Cretaceous-age (approximately 110 million years old) southern California batholith (Kgr). Most of the rocks exposed in the Chino Hills belong to the Puente Formation of Upper Miocene age. These sediments consist of friable sandstones with hard siltstone and shale interbeds and scattered conglomerate lenses. The basement complex does not outcrop in the immediate project area. Oil well data indicate that the top of the basement rocks is at an average depth of 4000 feet below sea level near the Chino fault, decreasing to about 1000 feet below sea level in the area north of the Prado Flood Control Basin. The nearest exposures of basement rock occur in a group of low hills east of the Santa Ana River north of Corona (see pl. B-3). The Chino Hills and the Puente Hills to the northwest are a structural unit that has been uplifted between the Whittier fault, which forms the southwest margin, and the Chino fault, which forms the east margin of these hills. Uplift of the region occurred during the past 2 to 3 million years (Quaternary

time) and deformed the Puente Formation with extensive warping and faulting. The warping generally trends northwest-southeast, paralleling major faults. Several very pronounced folds known as the Mahala anticline, Arena Blanca anticline, and the Arena Blanca syncline project through the Chino Hills near Prado Dam. There are numerous minor faults between the Whittier and Chino faults, which trend in two general directions, northwest-southeast, or parallel to the major faults, and northeast-southwest, normal to the major faults.

Site Geology

2-05 The general site geology for the various project elements is discussed in the following paragraphs and is presented on plate B-3. A detailed description of the geologic conditions along the proposed outlet works alinement through the left abutment of Prado Dam is presented in section X.

DAM

2-06 The abutments, spillway and outlet works of Prado Dam are founded on the same Puente Formation exposed in the Chino Hills. The streambed portion of the dam is founded on alluvium up to 90-feet thick. The foundation bedrock is composed of the uppermost portion of the Puente Formation known as the Sycamore Canyon member (designated Tpsc on plate B-4). The rock is locally characterized by white friable sandstones interbedded with conglomerates and brown, very fine-grained sandstones and siltstones. The white sandstones are poorly cemented, locally resembling tightly packed sand. When dry, the sandstones range in hardness from moderately soft to moderately hard, but lose much of their coherency when wet. Grain size ranges from fine to coarse, occasionally increasing to gravel size in the conglomeratic intervals. Conglomerate lenses or intervals are numerous in the hills adjacent to the right abutment, but decrease markedly under the dam and spillway. The clasts are well-rounded pebbles of hard granitic and metamorphic rocks derived from the San Gabriel and San Bernardino Mountains to the north. The interbeds of very fine sandstone and siltstone are moderately hard to hard and very competent. The brown coloring is due to a clay matrix that has bound together the larger silt and sand grains. Generally, the siltstones are less permeable than the sandstones and conglomerates. Under the dam, the formations strike nearly parallel with the dam axis (E-W) and dip 65 to 70 degrees upstream (to the north). This attitude is favorable, in that the lower permeability siltstone layers form effective barriers to water seepage through the bedrock.

2-07 Holocene (Recent) alluvial materials occur in the Santa Ana River channel, the reservoir floor, and other water courses. These deposits reach a known maximum thickness of 90 feet under the embankment and consist of saturated sands with smaller lenses of silt, gravel, and clay. In general, the alluvium becomes coarser with depth. Older (Late Pleistocene age) alluvial deposits consist of terraces and other deposits occurring at elevations above the Recent alluvium. Older

alluvium caps the hill between the dam and spillway and beyond the spillway to the southeast, and also occurs in the spillway approach. In summary, the older alluvium includes a thick sand and gravel unit overlain by a thin and discontinuous fine-grained sand and silt deposit. These are partially overlain by a wedge of reddish gravelly fan deposits and poorly bedded clayey and gravelly silts and sands. A well developed paleosol has developed across these units, especially in the lowermost unit where it exhibits clay enrichment, a deep red color, prominent pedogenic structures and calcite accumulations. The total thickness of the older alluvium is up to at least 75 feet in the left abutment area of the dam.

BORROW AREAS AND DIKES

2-08 The general site geologic conditions for borrow area nos. 1 and 2, the auxiliary dike, and the dikes at the California Institution for Women, the Alcoa Aluminum Plant, the Corona Sewage Treatment Plant, and the Corona National Housing Tract tend to be similar and thus are summarized in the following two paragraphs. The different site geology for the dike at the Corona Expressway is described separately in paragraphs 2-11 and 2-12.

2-09 Bedrock does not outcrop within the limits of borrow area nos. 1 and 2 or along the alinements of the proposed dike structures mentioned above. During the field investigation programs, bedrock was not encountered or identified, except in borings by Woodward-Clyde Consultants (1980) in the plateau immediately southeast of the spillway near the alinement of the proposed auxiliary dike. Sandstone, representative of the Sycamore Canyon member of the Puente Formation, was present at an average depth of 35 feet, eventually dropping off to depths below 75 feet beneath borrow area no. 1 (to the east), and to unknown depths along the proposed dike alinement (to the southeast). The bedrock recovered was brown and gray to olive gray and white, fine to coarse grained, and loose to moderately well indurated. Information on depths to bedrock in the Prado Flood Control Basin is limited. However, the top of bedrock in the central portion of the basin near borrow area no. 2 is estimated to be at a depth of about 200 feet (Durham and Yerkes, 1964).

2-10 Holocene (Recent) alluvial materials present consist of two types: (1) active stream channel and associated floodplain deposits of the Santa Ana River, Temescal Wash, and other water courses, including those incised stream courses on the Corona compound alluvial fan; and (2) lacustrine deposits in the Prado Reservoir. Older, generally Late Pleistocene-age alluvial sediments include terrace deposits along the northeastern flank of the Santa Ana Mountains and along the Santa Ana River and some of its larger tributaries, and alluvial fan deposits in the Corona area.

DIKE AT CORONA EXPRESSWAY

2-11 The proposed Corona Expressway (Highway 71) dike extends along the southeastern flank of the Chino Hills north from the right abutment area of Prado Dam. The Sycamore Canyon member is well exposed in highway

cuts along the axis of the Arena Blanca syncline in this reach. The bedrock is composed of an upper massive, white, coarse grained sandstone with poorly defined beds and lenses of conglomerate, grading downward into alternating beds of white sandstone and gray or greenish-gray siltstone ranging from a few inches to several feet in thickness. The exposed stratigraphic section contains the youngest beds exposed in the Sycamore Canyon member, and the upper portion of massive sandstone may be Pliocene in age (Durham and Yerkes, 1964). The bedrock dips moderately to the northeast on the southern limb of the Arena Blanca syncline, with moderate southward dips across the axis of the syncline. Bedrock exposures below the existing highway along the proposed dike generally occur on the upper half of the slope. Downslope from the contact, the depth to bedrock is assumed to increase gradually to the east. Along the base of the existing hill, depths to bedrock are variable and may reach 25 to 30 feet in some areas.

2-12 Older alluvial and terrace deposits of Late Pleistocene age comprise the principal surficial materials in the vicinity of the Corona Expressway. They occur mostly in the hills north of the project area. In the vicinity of the dam, thin older alluvial deposits mantle the gentler hillside slopes. Recent sediments fill the bottoms of the canyons along the edge of the Chino Hills as well as some of the small narrow hillside gullies.

III. GROUNDWATER

Groundwater Basins

3-01 The Upper Santa Ana Valley structural basin contains numerous natural groundwater basins, some the result of bedrock prominences partially isolating portions of the basin, and others the result of faults crossing the alluvium, forming nearly impermeable groundwater barriers. The basin contains upwards of 1000 feet of mostly Recent alluvial deposits covering the irregular bedrock floor. These sediments were derived principally from the granitic and metamorphic rocks of the San Gabriel and San Bernardino Mountains. In the region around Corona, the alluvium has been derived mostly from the Santa Ana Mountains. The sediments were laid down on alluvial fans and plains by streams draining the highland areas and consist generally of stringers and lenses of sand and gravel separated by layers of silt and clay. A groundwater study in the Corona area indicated the existence of a double aquifer system in the vicinity of the Corona Wastewater Percolation Ponds (U.S. Army Corps of Engineers, 1981). The upper aquifer, consisting of a 55 to 70-foot thick section of permeable sands and gravels, is separated from underlying less permeable sands and silts by a 5 to 20-foot thick layer of fine-grained material.

3-02 Prado Dam and that portion of the adjoining Prado Dam Flood Control Basin west of the Santa Ana River lie at the southwestern edge of the Chino Basin, the largest basin in the Upper Santa Ana Valley. The basin is located in the central and western part of the valley and all its boundaries, except the southern boundary (Santa Ana River) are determined largely or entirely by faults. That portion of the project area east of the Santa Ana River lies at the northern edge of the Temescal Basin, which occupies the northwest end of the Elsinore structural trough. The Temescal Basin is situated in the southwest corner of the Upper Santa Ana Valley. The Chino and Elsinore fault zones form the southwest boundary of the basin, while the southeast and northeast margins are formed by a group of low-lying hills crossing the trough and the low-lying hills of the Perris structural block, respectively. Underflow from adjacent basins and recharge from runoff

and rainfall are the main sources of groundwater in the basins. The groundwater moves south in the western part of the project area, and west and southwest in the eastern part, converging toward Prado Dam.

Historic Groundwater Conditions

3-03 Groundwater levels in the Upper Santa Ana Valley have fluctuated over the years as a result of variations in such features as precipitation, land use, the amount and rate of groundwater withdrawal, and the amount and rate of artificial recharge by water importation (Carson and Matti, 1985). Changes in water use and water management policies in particular have contributed to rapid short-term variation in local groundwater tables. The groundwater study conducted in the vicinity of the Corona Municipal Airport (U.S. Army Corps of Engineers, 1981) concluded that a definite lag pattern, on the order of four years, exists between a period of high annual precipitation and a period of high annual peak groundwater levels. Heavy precipitation in 1977, 1978, and 1979 caused a rise in groundwater levels in the Prado Flood Control Basin in 1981. Recent groundwater data for the project area is limited, because of the curtailment of monitoring activities within the past 30 years (Woodward-Clyde Consultants, 1980). However, numerous historical water-level records are available. A contour map of 1939-40, preconstruction groundwater levels, prepared by Woodward-Clyde Consultants (1980), indicated a trend of lower groundwater elevations toward Prado Dam, from elevation 600 feet in the northeast part of the project area to elevation 465 feet near Prado Dam. Depth to groundwater was from 0 to 10 feet in the dam area, up to 30 feet in the north, and from 5 to 30 feet along Temescal Wash in the south near Corona. Along the Santa Ana River, Mill Creek, and Chino Creek, water levels were very close to the surface and groundwater was probably discharging to the ground surface. Regional groundwater gradients calculated from the contour map varied from about 10 to 50 ft/mi. However, near the dam the gradient flattened to about 10 to 15 ft/mi.

Current Groundwater Conditions

3-04 Recent (post 1972) groundwater information obtained from limited water well records compiled by the California Department of Water Resources and from the various field exploration programs indicates that water levels in the project area have, in most cases, not changed significantly when compared with data from the 1939-40 period. During the May 1974 field investigations, the water table upstream of Prado Dam was at elevation 467 feet, dropping 24 feet to elevation 443 feet near the downstream toe. The difference in elevation between the upstream and downstream piezometric surfaces is due to the sheet pile cutoff wall beneath the dam. This cutoff wall interrupts the subsurface groundwater flow so that a substantial head loss results. In the northeastern portion of the project area, the water table has dropped an average of 20 feet, while in the Corona area, groundwater levels have risen an average of 5 feet. Groundwater levels in the vicinity of the Corona

Municipal Airport during the Corps of Engineers 1981 groundwater study were among the highest recorded within the past 50 years. The average depth to the water table was approximately 1 foot and groundwater contours reflected the local effects of recharge from the nearby Corona Wastewater Percolation Ponds upon the highly permeable upper aquifer materials. Water wells close to the active Santa Ana River channel have experienced relatively little change in water levels since 1939-40 because of the recharge from the river. Changes in water levels have resulted in overall flatter regional groundwater gradients since the 1939-40 period, averaging about 10 to 20 ft/mi. Downstream of the dam and in the hills to the west, the water table apparently steepens but the exact gradient is not known. The Chino fault, in the vicinity of the dam, apparently has little effect on the gradient. Groundwater elevations at the dam appear to reflect a continuation of the normal south to southwest flow in this area.

3-05 Recent groundwater conditions in the Prado Dam project area are shown on plate B-8. Two different sets of contour lines are presented. One set, with contours trending generally east-west, is from a study by Carson and Matti (1985). This contour set depicts minimum depths to groundwater and was constructed by contouring the shallowest water-level measurements reported to the California Department of Water Resources for the period 1973 through 1979. The majority of the project area lies within a zone of shallow groundwater (depths less than 50 feet). Depths to groundwater are shallowest (up to 10 feet) along the Santa Ana River channel and within the Prado Flood Control Basin, increasing to between 50 and 100 feet along the northern and southern margins of the project area. The second set of contours, which trend generally north-south, represent approximate groundwater elevations in feet, NGVD. This contour map was constructed by contouring post 1972 water level data obtained from published sources and from field investigations conducted by the Corps of Engineers. The groundwater contours in the vicinity of the Corona Airport and Wastewater Percolation Ponds reflect a 5 to 10 foot decline in water levels since the 1981 groundwater study.

IV. FAULTING AND SEISMICITY

Faulting

4-01 In southern California, the prominent northwest-southeast trending San Andreas fault can be considered as a boundary line in which the land west of it is drifting north relative to the east side. This drift builds up stresses throughout the region that are eventually relieved by movement along the San Andreas and other faults. The regional stress accumulated does not appear to be equally distributed among the faults as some move more frequently than others. Besides the San Andreas fault, the other major northwest-southeast trending faults, the San Jacinto, Whittier-Elsinore, and Newport-Inglewood, have been historically more active than other faults. Nine of the twelve largest and most recent earthquakes within approximately a 100-mile (162 km) radius of Prado Dam can be related to one of these four major fault zones (see table B-1). Innumerable smaller faults exist among them, most of which are considerably less active or apparently inactive.

Table B-1. Richter Magnitude 6+ Earthquakes Within 100 Miles of Prado Dam Since 1900[a].

Date	Probable Causative Fault	Richter Magnitude	Distance from site miles (km)
09/20/1907	San Andreas (?)	6.0	39 (63)
05/15/1910	Elsinore (?)	6.0	19 (30)
10/23/1916	(?)	6.0	100 (161)
04/21/1918	San Jacinto	6.8	38 (61)
07/23/1923	San Jacinto	6.3	21 (34)
03/11/1933	Newport-Inglewood	6.3	27 (34)

Table B-1. (Continued)

Date	Probable Causative Fault	Richter Magnitude	Distance from site miles (km)
03/25/1937	San Jacinto	6.0	86 (139)
04/10/1947	Manix (?)	6.2	98 (159)
12/04/1948	Mission Creek	6.5	72 (117)
03/19/1954	Coyote Creek (San Jacinto)	6.2	94 (152)
04/09/1968	Coyote Creek (San Jacinto)	6.4	100 (162)
02/09/1971	San Fernando (Sierra Madre)	6.4	57 (92)

(a) from Yerkes (1985) and Real and others (1978).

4-02 The location of Prado Dam in relation to the general trend of regional faulting is presented on plate B-9. The major faults and fault zones within a 100-mile radius of the dam are also shown on plate B-9. The major fault zones which could cause significant ground motions at the dam and their seismic evaluation parameters were recommended by Jeffrey A. Johnson, Inc. (1981) under contract to the Los Angeles District. A tabulation of the fault zones, fault length, distance to the site, moment magnitude, peak horizontal bedrock acceleration, and duration of strong shaking attenuated to the damsite is presented in table B-2.

Table B-2. Recommended Seismic Evaluation Parameters.

Fault	Fault Length (km)	Source/Site Distance (km)	Moment Magnitude (Mw)	Horizontal Bedrock Acceleration (g)	Duration (sec)
San Andreas	1100	44	8+	0.30	40
Newport-Inglewood	80+	38	6.5-7	0.20	25-30
San Jacinto	270+	37	7-7.5	0.25	25-30
Sierra Madre	100	26	6.5-7	0.30	30
Whittier-Elsinore					
Chino	21	1	6-6.5	0.50	15
Whittier	50	2.5	6.5-7	0.60	30
Elsinore	175	15	7-7.5	0.40	30

4-03 The two fault zones which dominate the seismic environment at the dam are the San Andreas and Whittier-Elsinore. The San Andreas fault was selected as the regional fault capable of generating the regional design earthquake and the Whittier fault was selected as the local fault capable of generating the local design earthquake to be used in the dynamic analyses. The fault selections were based upon the degree of activity of faulting, moment magnitude, peak site horizontal bedrock acceleration, and duration of strong shaking.

4-04 The San Andreas fault zone, the most dominant seismotectonic structure in California, is located approximately 27 miles (44 km) northeast of the dam. Recent investigations postulate that the San Andreas fault has produced twelve 8+ magnitude earthquakes during the last 1700 years (Ziony and Yerkes, 1985). The nearest 8+ earthquake on the San Andreas fault was the Fort Tejon event of 1857 which caused a surface rupture from near San Bernardino in the south to near King City in the north, a distance of approximately 250 miles (400 km).

4-05 Jeffrey A. Johnson, Inc. (1981) assumed the Whittier-Elsinore fault zone to be composed of three faults; the Whittier, Elsinore, and Chino faults. The Whittier-Elsinore fault zone is a northwest trending structure extending from the Coyote Mountains in the south to Whittier Narrows in the north. The fault zone separates into the Chino and Whittier faults near Corona. The fault zone exhibits both right lateral and dip-slip separation. Stratigraphic relationships between Miocene and Pliocene age rocks suggest that 3 miles of lateral displacement has occurred along the Whittier fault in the Puente Hills (Yerkes, 1972). The most impressive geomorphic and topographic evidence for recent ground surface rupture is found to the south along the Elsinore fault. The Elsinore fault is located about 15 miles southeast of Prado Dam while the Whittier and Chino faults both lie within approximately 1.5 miles of the site.

4-06 The Chino fault trends approximately N40°W for about 13 miles along the northeastern margin of the Puente Hills and the Santa Ana Mountains. In the Puente Hills, the fault offsets members of the Upper Miocene Puente Formation. In the Prado Dam area and to the south, the fault can only be observed in a few places where it cuts older alluvial and terrace deposits or where it forms northeast-facing scarps on these units. The fault dips steeply to the southwest and appears to have experienced both reverse dip-slip and right-lateral displacement. The fault is presumed to have become active during Middle Pleistocene time (Durham and Yerkes, 1964) and has been active at least through the Late Pleistocene. Woodward-Clyde Consultants (1980), under contract to the Los Angeles District, conducted a study at the damsite to locate and determine the recency and magnitude of faulting, particularly along the Chino fault. The study indicated that the most westerly splay of the Chino fault extends upstream of the dam, 500 feet northeast, and parallel with the spillway crest (see pls. B-4 and B-5). Near the spillway, the fault is a zone 300 feet wide consisting of discontinuous and imbricated segments associated with a monoclinal fold. The fault has displaced bedrock against older alluvium. The most recent movement

is estimated to have occurred less than 500,000 years ago, but probably more than 125,000 years ago; no definite age could be set on the last movement. Woodward-Clyde Consultants based on the amount of vertical deformation on the well-developed paleosol present in the vicinity of the spillway forebay, estimated the amount of movement on the Chino fault in the last 125,000 years to be on the order of 25 feet, including folding. This would produce a very low average vertical deformation rate for the fault of approximately 0.0025 in/yr. While some right-lateral faulting is suspected, no direct measurements were possible. A schematic representation of the Chino fault zone near the spillway is shown on plate B-10. The Woodward-Clyde studies also indicated apparent continuity of bedrock structure along the dam embankment which would preclude significant faulting under the dam.

Potential Fault Hazards

4-07 Based upon a review of the 1980 Chino fault study by Woodward-Clyde Consultants and recorded observations of main, branch, and secondary surface fault ruptures during moderate to large earthquakes, Prado Dam lies within a zone of potential surface fault offsets and ground cracking that could be triggered by an event along the Whittier-Elsinore fault zone (Jeffrey A. Johnson, Inc., 1981). In addition, the potential for future minor bedrock fault offsets cannot be discounted because of the discontinuous nature of bedding plane faults and the possibility of seismic and continuous aseismic deformation along the Chino fault zone. Significant surface fault rupture beneath the dam during the design life would be remote due to the apparent absence of major faulting beneath existing structures and the relatively minor historic activity along the Whittier-Elsinore fault zone as compared to the San Andreas, San Jacinto, and Newport-Inglewood fault zones.

Regional Seismicity

4-08 Prado Dam is located in Zone 4 of the Seismic Zone Map of the Contiguous States (U.S. Army Corps of Engineers, 1983), an area of high seismic potential. The California Institute of Technology's seismologic data base for southern California, Nevada, and Arizona indicates that a total of 664 Richter magnitude 4.0 and greater earthquakes have occurred within a 100-mile radius of Prado Dam between February 1932 and January 1987. Approximately 90 percent of the events had magnitudes between 4.0 and 4.9. A plot of their epicenter locations, including magnitude 6.0 or greater events since 1900, are shown on plate B-9. The most significant regional earthquakes (Richter magnitudes of 6.0 or greater) and their likely fault sources are listed in table B-1.

4-09 Jeffrey A. Johnson, Inc. (1981) determined the mean recurrence rate for magnitude 5 to 8 earthquakes based upon the regional seismic activity occurring within a 100-mile radius of the dam between 1800 and 1974. If the general level of seismicity were to remain consistent for the next 50 to 100 years, then data on earthquake magnitude versus

frequency of occurrence relationships and geologic information on mean recurrence rates along the San Andreas fault would appear to indicate that the project area has a distinct possibility of being exposed to the following level of regional seismic activity:

a. A magnitude 5.0 to 5.9 earthquake once every 2 years,

b. A magnitude 6.0 to 6.9 earthquake once every 9 years,

c. A magnitude 7.0 to 7.9 event every 174 years or less, and

d. A repeat of the 1857 magnitude 8+ event on the San Andreas fault within the next 125 years.

Local Seismicity

4-10 The local seismicity in the vicinity of Prado Dam is dominated by activity on the San Jacinto, Whittier-Elsinore, and Newport-Inglewood faults. Plate B-11 shows an epicenter plot of recorded Richter magnitude 2.0 and greater earthquakes within a 25-mile radius of the dam between February 1932 and January 1987. Those events with magnitudes of 4.0 and greater have been highlighted. The 1933 Long Beach earthquake, with a Richter magnitude of 6.3 and an epicenter location 27 miles southwest of Prado Dam and the 1 October 1987 Whittier Narrows earthquake, with a Richter magnitude of 5.9 and an epicenter location 28 miles northwest of the Prado Dam, have also been included since they were the largest instrumentally recorded events to occur near the project area. In general, Prado Dam is located in an area of rather diffuse and non-significant, low-magnitude seismicity. The California Institute of Technology's 55-year computer record lists 1914 magnitude 2+ events as having occurred locally. However, only 20 percent of the earthquake records had assigned Richter magnitudes equal to or greater than 3.0, and of these only 2 percent had magnitudes of 4.0 and above. A magnitude 5.5 earthquake in 1938, with an epicenter location 15 miles to the southeast of the dam, was the closest instrumentally recorded large magnitude event. Using the attenuation curves for horizontal accelerations in rock, developed by Schnabel and Seed (1973) and Greensfelder (1974), this earthquake plus the three local magnitude 6 events shown in table B-1 would have produced maximum rock accelerations of less than 0.15g at the dam. Prado Dam, since its construction in 1941, has never experienced any damage from either local or distant earthquakes. The largest post-construction earthquake to occur locally was the aforementioned Whittier Narrows event in October 1987. This earthquake produced a peak horizontal bedrock acceleration of 0.07g at the dam as recorded by the accelerometer on the left abutment.

Induced Seismicity

4-11 Changes in the seismic activity of a region have been related to the impoundment of water in certain, mostly large reservoirs (Simpson, 1976; Patrick, 1977). These changes range from various levels of micro-earthquake activity to damaging earthquakes with Richter

magnitudes greater than 6. The maximum worldwide reservoir-induced earthquake to date was the 1967 magnitude 6.5 event at Koyna, India, and although still larger events are not physically impossible, planning for them seems unreasonable (Allen, 1982).

4-12 A large reservoir is defined as one with a volume of at least one million acre-feet, usually impounded behind a dam 300 feet or greater in height (Johnson and others, 1977). The Koyna Dam, for example, is approximately 340 feet high and has a reservoir capacity in excess of 2 million acre-feet. The mechanisms responsible for producing reservoir-induced seismicity are poorly understood although the effects of reservoir loading and/or increased pore water pressure may be the most significant contributors to this phenomenon. Both these processes attribute the resulting seismicity to movement on a fault, but differ in the manner in which the induced stress field causes the movement to occur. Increased vertical stress due to the load of the water in the reservoir itself and decreased effective stress due to increased pore pressure can modify the stress regime in the reservoir region and cause fault movement and an earthquake. However, whether induced seismicity actually occurs depends on the way in which these stresses interact within the complete tectonic, geologic, and hydrologic environment.

4-13 Reservoir-induced earthquakes have generally started soon after impounding and for 5 to 10 years afterwards (Johnson and others, 1977), with the largest tremor usually occurring at or near the time of highest water level (Simpson, 1976). The possibility of an earthquake being generated by impoundment of water in Prado Reservoir is considered unlikely because the dam is presently only 106 feet high, has a reservoir capacity of less than 225,000 acre-feet, and experiences a relatively short duration pool storage.

4-14 Special consideration for reservoir-induced earthquakes at Prado Dam is not necessary because large naturally occurring design earthquakes have already been specified. The dynamic stability analyses of Prado Dam for various normal operating pool conditions (see Section XIV) did not disclose any geotechnical features that would affect the safety of the dam during a regional design earthquake (magnitude 8+ event on the San Andreas fault) or a local design earthquake (magnitude 6.5 to 7.0 event on the Whittier fault).

V. EXISTING EMBANKMENT AND CONSTRUCTION DATA

Dam Embankment

5-01 The existing Prado Dam was completed in 1941. It is a zoned compacted earthfill flood control structure located on the Santa Ana River, 4 miles west of Corona in the county of Riverside, California. The site plan is presented on plate B-12. The as-constructed foundation treatment is presented on plate B-13. The pertinent data of the dam and appurtenant structures are presented in table B-3.

Table B-3. Pertinent Data Existing Dam.

Drainage area	sq mi	2,255
Dam (rolled earthfill)		
Crest elevation	ft msl (NGVD)	566
Maximum height above streambed	ft	106
Crest length	ft	2,280
Freeboard	ft	10
Spillway (detached, overflow concrete)		
Crest elevation	ft msl	543
Crest length	ft	1,000
Elevation of maximum water surface	ft msl	556
Outlet works (6 - gates)		
Conduit Dimension	ft	13.5x13.5
Length of conduit	ft	750
Intake elevation	ft msl	460
Reservoir		
Area of spillway crest	acre	6,695
Capacity (gross) at spillway crest	acre-ft	217,000
Storage allocation below spillway crest		
Flood control	acre-ft	205,000
Sedimentation (50-year storage)	acre-ft	12,000

Table B-3. (Continued)

Reservoir-Design flood		
Total volume (7 days)	acre-ft	275,200
Peak inflow	cfs	193,000
Peak outflow	cfs	9,350
Probable Maximum Flood		
Total volume	acre-ft	233,000
Peak inflow	cfs	289,000
Peak outflow	cfs	181,000

5-02 The existing embankment has a crest length of approximately 2,280 feet and a top width of 30 feet. The top elevation is at elevation 566 feet and the maximum height above streambed is 106 feet. The total volume of the embankment is approximately 3.9 million cubic yards. The embankment slopes vary as shown in table B-4. See plate B-14 for a typical embankment section.

Table B-4. Prado Dam Existing Embankment Slopes.

Upstream Slope		Downstream Slope	
Slope	Elevation (ft, NGVD)	Slope	Elevation (ft, NGVD)
1V on 2.5H	566 to 536	1V on 2.5H	566 to 536
1V on 3H	536 to 510*	1V on 3H	536 to 525*
1V on 3H	510* to base	1V on 5H	525* to 495*
		1V on 6H	495* to base

(*) Location of 20-foot wide berm.

5-03 The embankment section consists of four zones: (1) upstream pervious zone, (2) random zone, (3) select impervious central core zone, and (4) downstream pervious zone. The upstream and downstream pervious materials were obtained from the required spillway excavation. Random materials were obtained from other required excavation and from a borrow area located northeast of the spillway. Core materials were obtained from a borrow area east of the left abutment and from surface materials excavated from the spillway. Average gradations of the four zones and plasticity charts for the random and core zones obtained from the 1972 and 1975 field investigations are shown on plate B-46.

5-04 Table B-5 summarizes the compactive effort, average density, and moisture content for each embankment zone. All materials were placed in 6-inch layers before compaction.

Table B-5. Compaction Data for Embankment Materials.

Material Zone	Compactive Effort No. of Passes (Equipment Used)	Average Dry Density (lb/ft^3)	Average Moisture (Percent)
U.S. Pervious	4-6 (drum roller)	130.1	9.3
Random	8 (sheepsfoot)	124.5	10.9
Core	8 (sheepsfoot)	118.6	12.9
D.S. Pervious	4-6 (drum roller)	127.4	9.8

Dam Embankment Foundation

FOUNDATION TREATMENT

5-05 The dam embankment foundation was stripped to varying depths. Foundation stripping beneath the streambed portion of the embankment extended to about elevation 454 feet. An area near the left abutment, extending from the upstream toe to 240 feet downstream of the dam axis between stations 16+75 and 22+00, was excavated to about elevation 428 feet to remove extensive silt and clay layers. Plate B-13 presents the extent of foundation stripping.

FOUNDATION TRENCH

5-06 After stripping, a foundation trench, with a bottom width of 40 feet and 1V on 1H side slopes, was excavated to elevation 448 feet between stations 5+00 and 17+50. A cutoff below the trench was provided by steel sheet piles driven to refusal in sandstone between stations 5+01 and 22+21. The pile depths vary from 13 feet at the right abutment to a maximum of 76 feet in the valley floor. The top of the sheet pile is at elevation 458 feet. Bedrock penetration was 2 to 3 feet in the streambed and 8 feet in the abutment. The row of sheet piling terminates at the beginning of the concrete cutoff walls in each abutment. The trench was backfilled with select impervious materials. See plate B-13 for the extent of the sheet pile and the foundation trench.

ABUTMENTS

5-07 After stripping of the shallow unconsolidated materials from each abutment surface, a narrow keywall trench, the limits of which are shown on plate B-13, was excavated along the dam axis and a concrete keywall placed in the trench. On the left abutment, the concrete keywall joins with the "X-Y" trench keywall, which extends through the left abutment to the spillway crest. The "X-Y" trench was backfilled with select impervious materials to original grade.

Dam Embankment Construction

5-08 The dam embankment was constructed in three phases to incorporate diversion and control of water during construction. The first phase consisted of constructing the embankment between station 8+00 and the left abutment to elevation 525 feet. The second phase or closure section was initiated after completion of the outlet works and consisted of construction of the embankment from the right abutment to station 8+00 to meet the phase one embankment top elevation. The third phase consisted of completing the embankment to elevation 566 feet.

VI. FIELD INVESTIGATIONS AND SAMPLING

General

6-01 Previous reports on Prado Dam were researched to obtain available foundation and embankment materials data for this appendix. Much of the data were obtained from the Prado Dam Foundation Analysis report (U.S. Army Engineer District, 1976) and Prado Dam Design for Major Rehabilitation report (U.S. Army Engineer District, 1985, Draft). Supplemental investigations were conducted for this appendix to obtain data for the outlet works and dikes.

Dam Embankment and Foundation

6-02 Subsurface field investigations were conducted in 1972, 1974, 1975, 1976, and 1980. The investigations consisted of drilling 42 bucket-type power auger holes (each 16 inches in diameter) and 45 Failing 1500 or CME 55 rotary drill holes (either 5 or 6 inches in diameter). The borings, by date and general location, are summarized in table B-6. The locations of the field investigations are presented on plate B-18.

6-03 The subsurface investigations were conducted to obtain standard penetration test (SPT) data and disturbed bulk and undisturbed samples. The disturbed and undisturbed samples were tested to obtain gradations, in-place densities, and static and dynamic strength and response characteristics. The SPT results and material properties were used to develop subsurface soil profiles.

Table B-6. Summary of Borings.

Date	Boring Number	General Location
1972	TH72-1 to 15(1)	Foundation & Embankment
Jul-Aug 1974	9F-16F(2)	Foundation
Jan-Feb 1975	TH75-1 to 4, 31 to 34, 49 to 71	Foundation & Embankment
	TH75-7 to 30, 35 to 48	Borrow
Mar-May 1975	17F-35F	Foundation & Embankment
Oct 1975-Jan 1976	37F-48F	Foundation
Nov-Dec 1980	49F-54F	Foundation

Notes: 1. TH designates 16-inch diameter bucket auger
2. F designates Failing 1500 or CME 55 drill rigs

6-04 Disturbed bulk samples were obtained from the bucket auger holes for mechanical analysis. Undisturbed samples were obtained from the Failing 1500 and CME 55 drill borings. The July 1974 drilling program was conducted to obtain undisturbed samples for material classification and density. Undisturbed samples for dynamic laboratory tests were obtained from the March 1975 drilling program. The October 1975 drilling program was conducted to obtain additional SPT data and determine the material density. The 1980 exploration program was conducted to obtain undisturbed samples for dynamic testing. The procedures used to sample and transport these undisturbed samples are described in paragraphs 6-06 through 6-09.

6-05 Each boring was continuously logged using the Unified Soil Classification System (ASTM D 2487). The logs of the test borings are shown on plates B-20 through B-30 and B-32 through B-35. Undisturbed soil sampling was attempted at 5-foot increments, from depths of 20 to 50 feet. Standard penetration tests were conducted after each undisturbed sampling attempt.

6-06 The undisturbed samples were obtained with a Pitcher barrel using thin wall Shelby tubes having an inside diameter of 2.875 inches. Each sample obtained was maintained vertically and voids at the end of the tubes were filled with Ottawa sand. Perforated packers and filter paper were placed on the end of each sample. The samples were stored vertically and allowed to drain for at least 24 hours. After draining, a vacuum of less than 7 lb/in^2 was applied to the samples to remove any free water. After vacuuming, the samples were frozen in the field in increments from the bottom to top using dry ice. After freezing, the samples were transported in freezer storage and X-rayed prior to shipping to the South Pacific Division (SPD) laboratory.

6-07 Samples taken for density determination were obtained either by Hvorslev fixed piston or Pitcher sampler. Test samples for dynamic testing were obtained either by an Osterberg piston or Pitcher sampler. In general, the Pitcher sampler was used to sample compacted embankment materials, foundation materials below depths of about 30 feet, or materials containing gravel. Hydraulic pressure was used to push the samplers. The average drive pressure for each half-foot of advance was noted to obtain a record of the driving resistance.

6-08 Perforated end packers were used to drain density samples vertically in the field immediately after they were taken. Non-perforated packers or wax and end caps were used to immediately seal samples taken for dynamic laboratory tests for both the foundation sands and compacted embankment materials. All samples were placed horizontally in racks, stored in the shade, and carefully transported to testing destinations on a rack placed horizontally on a mattress.

Outlet Works

6-09 Geotechnical investigations for the proposed outlet works relocation through the left abutment were conducted between December 1982 and April 1987. The investigations consisted of geologic mapping; rotary, core, and bucket auger drilling, backhoe trenching, shallow seismic refraction surveys, and field and laboratory testing. Prior to this phase of exploration, the only information available on the actual subsurface geology of the left abutment was developed from pre-construction exploratory borings. Therefore, a program of exploration and testing was initiated primarily to determine: (1) the thickness and nature of the overburden and bedrock materials, (2) the geologic structure and degree of faulting, and (3) the piezometric surface. The outlet works geology and overall plan of exploration is shown on plate B-52.

6-10 Nineteen rotary borings (R83-1 through R83-19) were drilled, using a CP-55 drill rig, to depths ranging from 5.5 to 138 feet at the locations shown on plate B-53. Geologic logs of these borings are shown on plates B-53 and B-54. The purpose of the drilling was to: (1) determine the bedrock/overburden contact elevation at the left abutment, (2) obtain samples of the bedrock for laboratory testing, and (3) install observation wells. Five core borings (C83-1 through C83-5) were drilled, using Failing 750, Mobil B61, and Longyear 44 drill rigs to depths ranging from 48 to 143 feet at the locations shown on plate B-55. The purpose of the drilling was to: (1) inspect continuous sections of the bedrock in order to identify bedding orientation, as well as the character of any significant discontinuities, (2) obtain additional samples for testing, and (3) provide boreholes for subsequent borehole photography. Five test trenches (TT83-1 through TT-83-5) and two test pits (TP83-1 and TP83-2) were excavated, using a backhoe, at the locations shown on plate B-56. The purpose of the trenching was to: (1) verify initial assumptions regarding the depth to bedrock made after the start of the geophysical explorations but prior to drilling,

and (2) confirm previously mapped surficial overburden/bedrock contacts in certain areas. Sixteen shallow seismic refraction surveys (RS82-1 through RS82-5 and RS83-1 through RS83-11) were conducted at the locations shown on plate B-57. The purpose of the surveys was to: (1) determine whether the anticipated shallow depth to bedrock at the left abutment as inferred from preconstruction borings and nearby bedrock outcrops was correct, and (2) determine the approximate depth to bedrock at a particular location prior to drilling. Four bucket auger test holes (TH87-101 through TH87-104) were drilled to depths ranging from 30 to 44 feet at the locations shown on plate B-52. The purpose of the drilling was to: (1) further refine the bedrock profile along the proposed outlet works alinement, (2) perform standard penetration tests to determine in situ density/consistency characteristics, and (3) obtain soil samples for laboratory testing. Summaries of the rotary, core, and bucket auger drilling programs are presented in tables B-7, B-8, and B-9, respectively.

6-11 Geologic logs of the rotary borings are shown on plates B-53 and B-54. Bedrock was encountered in 15 borings and the bedrock surface elevation was positively identified in at least 13 holes. Twenty undisturbed samples of the bedrock, averaging 1.2 feet in length, were collected in Shelby tubes using a Pitcher sampler. The samples were transported to SPD Laboratory for detailed laboratory testing. Additional disturbed samples of the bedrock and overburden were collected for mechanical analysis. Observation wells, consisting of perforated 3-inch diameter PVC pipe, were installed in 8 of the rotary borings. Geologic logs of the core borings are shown on plate B-55. Core recovery averaged less than 50 percent, the changes in the steeply dipping bedrock were generally indistinct and gradational, and holes could not be drilled that were suitable for borehole photography. Nonetheless, valuable information on bedrock depths and properties was obtained. Logs of the test trenches and test pits are shown on plate B-56. Compressional or P-wave velocity profiles obtained from interpretation of the geophysical survey data are shown on plate B-57. Soils logs of the bucket auger test holes are shown on plate B-58. Disturbed samples of the overburden materials were obtained from each boring at intervals of 3 feet or at each change in soil type. Representative undisturbed drive samples were also obtained. Standard penetration testing was conducted in each test hole in order to determine relative densities. Detailed laboratory testing of remolded and undisturbed samples was performed by SPD Laboratory.

6-12 Additional foundation investigations along portions of the outlet works alinement will be conducted during the Feature Design Memorandum stage to verify assumptions made regarding foundation conditions.

Table B-7. Outlet Works - Summary of Rotary Drilling.

Hole No.	Coordinates	Collar Elev. (ft)	Top of PVC Elev. (ft)	Total Depth (ft)	Bedrock Depth (ft)	Bedrock Elev. (ft)	Groundwater Elev. (ft)
R83-1	N 629,551 E 1,579,469	569.9	571.9	131.2	55+	515+	503
R83-2	N 629,463 E 1,579,368	571.9	--	160.5	54+	518+	--
R83-3	N 629,386 E 1,579,261	576.5	578.0	138.3	64.2	512.3	480
R83-4	N 629,505 E 1,579,247	575.1	--	72.9	71.5	503.6	--
R83-5	N 629,672 E 1,579,575	568.1	--	54.0	52.7	515.4	--
R83-6	N 629,739 E 1,579,665	565.5	--	49.6	--	--	--
R83-7	N 630,000 E 1,579,687	540.0	542.3	97.4	34.3	505.7	511
R83-8	N 630,125 E 1,579,797	513.5	--	54.5	37?	476-1/2?	501+
R83-9	N 630,105 E 1,579,797	522.3	522.8	66.7	30+	492+	504
R83-10	N 630,112 E 1,579,662	517.4	--	40.5	37-1/2	480	500+

Table B-7. (Continued)

Hole No.	Coordinates	Collar Elev. (ft)	Top of PVC Elev. (ft)	Total Depth (ft)	Bedrock Depth (ft)	Bedrock Elev. (ft)	Groundwater Elev. (ft)
R83-11	N 630,159 E 1,579,662	519.8	--	9-1/2	6+	514+	--
R83-12	N 629,154 E 1,578,836	471.4	473.3	56.2	54.2	417.2	449
R83-13	N 629,252 E 1,578,991	484.0	--	5-1/2	--	--	--
R83-14	N 629,258 E 1,579,013	486.0	488.2	58.5	21.3	464.7	471
R83-15	N 630,014 E 1,579,960	529.5	--	31.5	30.4	499.1	--
R83-16	N 629,762 E 1,579,295	570.0	572.8	116.2	51.5	518.5	500
R83-17	N 627,918 E 1,578,785	465+	--	55	--	--	445+
R83-18	N 629,900 E 1,579,432	563.5	565.7	127.9	47.0	516.5	--
R83-19	N 629,166 E 1,579,228	576	--	38	35	541	--

Table B-8. Outlet Works - Summary of Core Drilling.

Hole No.	Coordinates	Collar Elev. (ft)	Total Depth (ft)	Bedrock Depth (ft)	Bedrock Elev. (ft)	Core Recovery (percent)
C83-1	N 629,965 E 1,579,615	546.0	48	43	503	n.a.
C83-2	N 629,750 E 1,579,505	568.0	130.1	53-1/2	514-1/2	72
C83-3	N 629,520 E 1,579,368	572.1	143.4	76.3	495.8	19
C83-4	N 630,000 E 1,579,580	542.1	129.0	31	511	54
C83-5	N 629,945 E 1,579,645	545.7	101.7	38-1/2	507	31

Table B-9. Outlet Works - Summary of Bucket Auger Drilling.

Hole No.	Coordinates	Surface Elev. (ft)	Total Depth (ft)	Bedrock Depth (ft)	Bedrock Elev. (ft)	Groundwater Elev. (ft)
TH87-1	N 630,245 E 1,579,600	510	38	38?	472	494
TH87-2	N 630,295 E 1,579,730	507	44	37.5	469.5	490
TH87-3	N 629,065 E 1,578,285	470	40	--	--	441
TH87-4	N 628,960 E 1,578,055	466	30	--	--	--

Spillway

6-13 *Explorations* conducted between 1970 and 1975 were oriented toward the alternatives of widening the existing spillway or constructing a new auxiliary spillway through the hills immediately west of the dam. This alternative has since been abandoned. The location of the borings are shown on plate B-63. Two 6-inch and one 4-inch diameter core holes were drilled along a line 200 feet upstream from the existing spillway crest. In addition, shallow refractive seismic surveys were conducted and backhoe trenches were excavated between the core holes and on the terrace to the east. Unconfined compression tests were conducted on selected cores from the borings. At the auxiliary spillway site, one 4-inch and one 6-inch diameter core hole were drilled in the proposed crest area, and the site geology was mapped. Logs of the core holes are shown on plate B-63.

Borrow Area No. 1

6-14 Thirty-eight borings (TH75-7 through TH75-30 and TH75-35 through TH75-48) were drilled using a 16-inch diameter bucket-type power auger to investigate potential borrow areas during January and February 1975. Additional investigations for potential borrow areas consisted of drilling 24 borings in November 1979 and 23 borings (TH80-1 through TH80-23) in April 1980 using a 16-inch diameter bucket-type power auger and excavating 22 trenches with a backhoe in November 1979. The locations of the borings and trenches are presented on plate B-19.

6-15 Each boring and trench was continuously logged using the Unified Soils Classification System (ASTM D 2487). The logs of the test borings and test trenches are shown on plates B-28 through B-31 and B-36 through B-43. Representative disturbed samples were taken at three foot intervals or less when materials changed for mechanical analyses. Large bag samples were taken of predominant material types for detailed laboratory testing.

Borrow Area No. 2

6-16 Four borings (TH85-1 through TH85-4) were drilled during March of 1985 and 12 borings (TH87-18 through TH87-29) were drilled during April of 1987 using a 24-inch diameter bucket auger to investigate potential borrow areas. The locations of the borings are shown on plate B-64.

6-17 Each boring was continuously logged using the Unified Soil Classification System (ASTM D 2487). The logs of the test borings are shown on plates B-65 through B-67. Representative disturbed samples were taken at three foot intervals or less when materials changed. Large bag samples were taken for detailed laboratory testing.

Dikes

6-18 General Design Memorandum phase investigations and design activities attempted to reduce the uncertainty about the site conditions and construction materials that would have significant impacts on the cost of the project. Final design for the dikes will include more extensive exploration and testing than could be accomplished within the time and cost constraints of the GDM. Additional investigations for each dike foundation will be performed during preparation of plans and specifications to verify conservative design assumptions.

6-19 Foundation conditions along the proposed alinements of the auxiliary dike, the dike at California Institution for Women, the dike at Alcoa Aluminum Plant, and the dike at Corona Sewage Treatment Plant were investigated in January 1987. Three test holes and 8 test trenches were placed in the area bounded by the Corona Municipal Airport and the Corona Sewage Treatment Plant to investigate potential borrow materials. The dike investigations are summarized in table B-10. The locations of the field investigations are presented on plates B-68, B-70, B-73, and B-75. The logs of the test holes and test trenches are shown on plates B-69, B-71, B-72, B-74, B-76, and B-77. Foundation conditions at the Corona National Housing Tract were not investigated during the GDM phase. Field exploration will be performed during preparation of plans and specifications.

Table B-10. Dikes - Summary of Borings and Trenches.

Test Hole/Test Trench	Location
TH75-12, -21, -22, -23 TH87-13, -15 TT87-17, -18, -19, -20, -21, -22	Auxiliary Dike
TH87-7, -7A, -8, -9, -11, -14 TT87-12, -13, -14, -15, -16, -27, -28	Alcoa Aluminum Plant
TH87-16, -17 TT87-23, -24, -25, -26	California Institution for Women
TH87-1, -2, -3, -4, -5, -6, -10, -12 TT87-1 thru -11	Corona Sewage Treatment Plant

6-20 Investigations were conducted using a 24-inch diameter bucket auger and a backhoe equipped with a 24-inch wide bucket. A water truck and revert were used in conjunction with the power auger after groundwater was encountered. Disturbed samples were taken every 3 feet or change of material, and composite samples were taken of the more prevalent materials encountered. Undisturbed Shelby tube samples were

alternately taken with SPT testing at 3-foot intervals in the test holes. Shelby tube samples were taken when fine-grained soils were encountered. Samples taken at depths above the water table were sealed with sand, wax, and packers at both ends. Samples taken from below the water table were sealed with sand, wax, and packers at the top and sand and perforated packers at the bottom. Undisturbed 12-inch cube samples were taken in the test trenches for each dike. In-situ density tests using the Sand Cone Method (ASTM 1556) were performed in the foundation and borrow area test trenches.

DIKE AT CORONA EXPRESSWAY

6-21 Geotechnical investigations for the proposed dike at the Corona Expressway were conducted in April 1987. The investigations consisted of geologic reconnaissance, bucket auger drilling, and field and laboratory testing. These investigations supplemented field explorations conducted in 1971 for the proposed auxiliary spillway site through the Chino Hills west of Prado Dam. The 1971 studies consisted of geologic mapping, core drilling, and bedrock permeability testing.

6-22 Investigations along the Corona Expressway were restricted by limited access along the expressway. Further investigations will be conducted during preparation of plans and specifications. One boring (TH87-30) was drilled, using a 24-inch diameter bucket auger, during April 1987. The location and log of the test hole is shown on plate B-78. The purpose of the drilling was to: (1) determine subsurface foundation conditions, and (2) obtain samples for laboratory testing. Two core holes, DD-55 and DD-56, were drilled in January 1971, using a Failing 1500 drill rig, to depths of 180.3 feet and 71.0 feet, respectively, at the locations shown on plate B-63. The original purpose of the drilling was to determine: (1) the subsurface geologic structure, (2) the rock mass permeability, and (3) the general bedrock excavation requirements for the previously considered and since deleted auxiliary spillway alternative. However, the results of drilling were also used in the evaluation of foundation conditions for the dike at Corona Expressway.

6-25 The test holes were continuously logged using the Unified Soil Classification System (ASTM D 2487). Large bag samples were taken for detailed laboratory testing. Disturbed samples of the overburden materials were obtained at intervals of 3 feet or at each change in soil type for mechanical analyses. The geologic logs of the two core holes are shown on plate B-63.

6-26 Standard penetration testing was conducted when possible in order to determine relative densities and the results are shown on the soils log on plate B-78. Data from pressure tests, conducted upon completion of each core hole, were used in the calculation of rock mass permeabilities.

6-27 The California Department of Transportation conducted a foundation investigation prior to constructing the Corona Expressway. The logs and location of the investigation are shown on plates B-79 through B-81.

VII. FIELD TESTING

Dam Foundation and Embankment

STANDARD PENETRATION TESTS

7-01 Standard penetration tests (SPT) during the 1975 investigations were conducted in mud-filled bucket auger borings and in most of the Failing 1500 drill holes. Standard Penetration Tests were conducted to obtain data on the relative compactness of the foundation materials and to identify loose zones. In accordance with ASTM D 1586, the test consisted of driving a sampling spoon, having an inside diameter of 1-3/8 inches and an outside diameter of 2 inches, with a 140 pound hammer falling from a height of 30 inches. The sampling spoon was driven 6 inches and the penetration resistance was recorded as the number of blows required to drive the sampler one additional foot. The hammer was raised with two turns of a rope around a cathead.

7-02 Since ASTM D 1586 specifies auger holes of 6.5 inches or less, side-by-side standard penetration tests were made to evaluate the effect of the size of the hole on the number of blows required to advance the sampler one foot. Standard penetration tests were conducted in both 16- and 5-inch diameter holes. Penetration tests were conducted in TH75-54, a 16-inch diameter hole, and in holes 39F and 40F, which were 5-inch diameter holes. The results of the tests are presented on plate B-47 and indicate that the different hole diameters had no appreciable effect on the resulting blow counts. Therefore, actual blow count data for all diameter holes were used.

7-03 Standard penetration tests were conducted in mud-filled rotary wash borings drilled in 1980. The drilling mud was maintained at a level above the water table.

FOUNDATION PERMEABILITY AND GROUNDWATER

7-04 Two sets of four piezometers each were installed to depths of approximately 20, 30, 40, and 50 feet in the reservoir area immediately upstream from the dam during January 1975 to serve as observation wells

during subsequent pump tests in July 1975, and to determine the existence of perched water, to locate any aquifers, and to measure the depth variations of foundation groundwater on the upstream side of the sheet pile cutoff. The locations of the piezometers and the pump test well are presented on plates B-18 and B-48. Cross sections of each piezometer set are presented on plate B-48. The results of the pump test were used to determine the average permeability of the foundation materials.

GEOPHYSICAL INVESTIGATIONS

7-05 Geophysical investigations for the dam foundation and existing embankment, consisting of surface refractive and crosshole and downhole surveys, were conducted in three phases to determine P- and S-wave velocities. The investigations conducted are summarized in table B-11. The locations of the geophysical investigations are shown on plate B-18.

Table B-11. Summary of Geophysical Investigations.

Type of Geophysical Investigation	Date
Surface Refractive (7 lines)	April to May 1974
Crosshole (8 sets)	April to May 1974
Surface Refractive (8 lines)	November 1975
Crosshole and Downhole (2 sets)	November to December 1980

7-06 The crosshole surveys were conducted at eight locations from April to May 1974 by the U.S. Army Engineer Waterways Experiment Station (WES). Three holes were drilled with a Becker hammer down to or near the bedrock surface at each location. One hole was designated as the source hole and the other two holes were designated as receiver holes. The receiver holes were located approximately 20 and 120 feet from the source hole. Each hole was cased with PVC pipe and the annulus around the casing was backfilled with sand. WES interpreted the data from the crosshole surveys and presented the results in Miscellaneous Paper S-75-6 (Curro and others, 1975).

7-07 Crosshole and downhole surveys were conducted from November to December 1980 to clarify inconsistencies in the data from the WES crosshole surveys. The crosshole and downhole surveys were conducted at two locations by Fugro, Inc. Consulting Engineers and Geologists. A set of three holes, spaced 15 to 20 feet apart, were drilled at each location using either a CME-55 drill rig set up for rotary wash drilling or a Failing 1500 drill rig. Each hole was drilled to a nominal depth of 50 feet and cased with PVC pipe. The annular space around the pipe in two of the holes in each set was grouted with concrete. The third

hole (downhole location) of each set had the annulus backfilled with sand. Fugro, Inc. interpreted the data from the downhole and crosshole surveys. The results of the surveys are summarized on plate B-49.

Outlet Works

STANDARD PENETRATION TESTS

7-08 During the 1987 investigations, SPT's were conducted in revert-filled bucket auger borings to obtain data on the relative compactness of the foundation materials and to identify loose zones.

GEOPHYSICAL INVESTIGATIONS

7-09 Sixteen surface refraction surveys were conducted along the proposed outlet works alinement through the left abutment between December 1982 and March 1983, see plate B-57. Seismic refraction profiling was accomplished utilizing a Geometrics 12-channel signal enhancement seismograph and explosive energy sources. Survey line lengths were either 165 or 330 feet. The surveys were intended to yield information on subsurface P-wave velocities and the overburden/bedrock contact. The results of the geophysical explorations are shown on plate B-57.

GROUNDWATER MONITORING

7-10 Observation wells were installed in rotary borings R83-1, R83-3, R83-7, R83-9, R83-12, R83-14, R83-16, and R83-18 drilled along the proposed outlet works alinement through the left abutment, see plate B-52. The wells consisted of 4-inch outside diameter schedule 40 PVC pipe with 4-1/2-inch outside diameter couplers. The bottom of each observation well was capped and the lower 5 to 10 feet was slotted with a coping saw or hacksaw. The annulus was backfilled with No. 16 silica sand to about 5 feet of the ground surface. The remaining annulus was filled, with a cement slurry. The wells were installed for the purpose of determining and monitoring the piezometric surface at the left abutment. Water levels were measured on a monthly or bimonthly basis between March 1983 and December 1983, again in October 1984 and March 1987. The observation well readings are shown in table B-12. Groundwater levels will continue to be monitored to determine any future changes in the left abutment piezometric surface.

Table B-12. Outlet Works - Observation Well Readings.

		Depth to Groundwater (ft)/Groundwater Elevation (ft)								
Date	Well No.: Elev. (ft):	R83-1 571.9	R83-3 578.0	R83-7 542.3	R83-9 522.8	R83-12 473.3	R83-14 488.2	R83-16 572.8	R83-18 565.7	Reservoir Elev. (ft)
03/28/83		69.2 502.7	98.5 479.5	31.0 511.3	18.1 504.7	25.9 447.4	17.5 470.7			499.8
04/04/83		68.5 503.4	98.0 480.0	30.5 511.8	18.9 503.9			72.8 500.0		
04/27/83		67.5 504.4	96.6 481.4	30.1 512.2	19.1 503.7	25.0 448.3	23.2 465.0	71.6 501.2	51.5 514.2	500.0
06/01/83		66.6 505.3	95.7 482.3	30.2 512.1	18.7 504.1	29.8 448.5	23.1 465.1	70.5 502.3	51.7 514.0	500.4
07/25/83		67.0 504.9	95.9 482.1	31.0 511.3	25.8 497.0	26.0 447.3	24.0 464.2	74.1 498.7	52.8 512.1	dry
08/15/83		66.3 505.6	95.5 482.5	31.2 511.1	26.5 496.3			74.7 498.1	52.2 513.5	dry
09/20/83		66.0 505.9	95.5 482.5	31.5 510.8	27.5 495.3	26.6 446.7	24.0 464.2	76.1 496.7	52.0 513.7	dry
10/18/83		66.6 505.3	95.8 482.2	31.9 510.4	27.8 495.0			76.7 496.1	52.0 513.7	
12/16/83		67.0 504.9	95.9 482.1	32.3 510.0	25.1 497.7	27.8 445.5	24.7 463.5	76.3 496.5	51.5 514.2	495.0
10/17/84		70.3 501.6	97.1 480.9	35.2 507.1	33.8 489.0	31.2 442.1	25.5 462.7	82.9 489.9	52.3 513.4	dry
03/25/87		73.3 498.6	99.0 480.9	38.2 504.1	30.5 492.3	30.7 442.6	27.4 460.8	79.1 493.7	52.0 513.7	

VIII. BORROW AREA EVALUATION

General

8-01 Field investigations, consisting of bucket auger holes and backhoe trenches, and laboratory test results, consisting of classification data, were used to define the potential borrow areas in terms of material types and engineering properties.

Borrow Area No. 1

8-02 The locations of test holes and test trenches for borrow area no. 1 are presented on plate B-19. Based on soil logs, borrow area no. 1 consists of two predominant material types. The upper layer or potential Zone II material varies in thickness from 1.5 to 37 feet and consists of cohesive silts, clays, sandy silts, and clays, and silty, clayey sands. Plate B-50 presents the gradational range of the potential Zone II materials. The Zone I materials below the potential Zone II materials, consist predominantly of coarse-grained silty and clayey gravelly sands and sandy gravels interspersed with lenses and layers of silts and clays and occasional cobbles up to 8 inches. Plate B-50 presents the gradational limits of Zone I materials.

ZONE I MATERIALS

8-03 The Zone I materials would be obtained by excavating and blending the coarse-grained materials located below the Zone II materials. Logs of borrow area no. 1 indicate the potential Zone I materials are covered by 1.5 to over 20 feet of Zone II materials. The Zone I materials consist predominantly of gravelly sands and silty and clayey gravelly sands. Using an average excavation depth of 4 to 6 feet, a statistical analysis of the percent passing the No. 4 and No. 200 sieves before and after blending and the unblended Atterberg Limits are presented in table B-13. The unblended and blended gradations are presented on plate B-50. Less than one percent of Zone I material would contain particles larger than 8 inches. Oversize material would be raked to the slope face.

Table B-13. Zone I Borrow Gradations.

			Percent Finer By Weight			
	Sieve Size No.	Coarse Limit	Lower Quartile	Median	Upper Quartile	Fine Limit
Unblended:	4	43	64	75	83	100
	200	1	6	9	13	99
Blended:	4	43	65	75	82	100
	200	1	7	10	14	24
Atterberg Limits:						
LL		-	-	-	-	53
PI		NP	NP	NP	NP	26

ZONE II MATERIALS

8-04 The Zone II materials would be obtained by excavating and blending the fine materials from the upper layer of the designated borrow area. Logs of borrow area no. 1 indicate the depth of potential Zone II materials varies from 1.5 to 37 feet. Using an average excavation depth of 4 to 6 feet, a statistical analysis of the percent passing the No. 4 and No. 200 sieves before and after blending and unblended Atterberg Limits of the potential Zone II material are presented in table B-14. Plate B-50 presents the unblended and blended gradations. Few cobbles and boulders larger than 9 inches would be encountered in the Zone II materials.

Table B-14. Zone II Borrow Gradations.

			Percent Finer By Weight			
	Sieve Size No.	Coarse Limit	Lower Quartile	Median	Upper Quartile	Fine Limit
Unblended:	4	59	96	99	100	100
	200	3	36	58	74	96
Blended:	4	59	96	99	100	100
	200	10	41	56	70	95
Atterberg Limits:						
LL		-	-	27	32	49
PI		NP	NP	8	13	32

Borrow Area No. 2

RANDOM MATERIALS

8-05 The locations of test holes for borrow area no. 2 are presented on plate B-64. Borrow area no. 2 consists of two predominant material types. The northern and southeastern portion of the borrow area contains coarser-grained material which consists of clayey gravelly sands with occasional cobbles and boulders. The remaining portion contains fine grained material which consists of sandy clay. The quantity of material required could be obtained from the entire borrow area with an average excavation depth of 15 feet. The materials are uniform in depth and may be excavated to depths greater than 15 feet in localized areas. The borrow area is shown on plate B-1. Borrow area no. 2 has been divided into sections A, B and C for environmental reasons (see Environmental Appendix) as shown on plate B-1.

8-06 Coarse Grained Material. The coarser-grained materials would be excavated from sections A and B of borrow area no. 2. Logs of these areas indicate that the materials are uniform to a depth of 40 feet. A statistical composite gradation of the coarse grained material to a 40-foot depth is presented in table B-15.

Table B-15. Coarse Grained Material Composite Gradations.

	Mechanical Analysis (Percent Finer)									
	Gravel (In.)				Sand (Sieve No.)					Fines
	3.0	1.5	3/4	3/8	4	10	16	40	100	200
Upper Limits	100	99	93	88	83	76	65	54	38	31
Upper Quartile	100	97	91	82	73	62	51	40	27	21
Mean (Average)	100	96	89	80	71	61	48	37	24	18
Lower Quartile	100	94	87	77	67	57	44	32	19	14
Lower Limits	100	94	86	77	67	55	43	30	17	12

8-07 Fine Grained Material. The fine grained materials would be excavated from section C of borrow area no. 2. Logs of this area indicate that the materials are predominantly finer-grained from 10 to 40 feet in depth, and are slightly coarser from 0 to 10 feet. The statistical composite gradation of the fine grained material to a 40-foot depth is presented in table B-16.

Table B-16. Fine Grained Material Composite Gradations.

	Mechanical Analysis (Percent Finer)									
	Gravel (In.)				Sand (Sieve No.)					Fines
	3.0	1.5	3/4	3/8	4	10	16	40	100	200
Upper Limits					100	97	94	92	81	74
Upper Quartile				100	99	96	89	83	70	61
Mean (Average)			100	99	98	95	88	82	69	58
Lower Quartile			100	99	98	93	86	79	68	54
Lower Limits		100	99	98	96	91	81	72	55	42

IX. DESCRIPTION OF FOUNDATION CONDITIONS

General

9-01 The results from field investigations and tests were used to depict foundation profiles of the dam embankment, outlet works and dikes. Design values were selected, based on interpretations of the data.

Dam Foundation

MATERIALS

9-02 The dam foundation soil logs are presented on plates B-20 through B-23 and B-25 through B-27. The logs indicate the foundation to be heterogeneous. A profile of the foundation materials along the centerline of the dam and a cross section at station 7+50 are presented on plate B-45. In general, these sections represent simplified typical foundation conditions indicating that the materials are predominantly cohesionless sands with some gravels, gravelly sands, and silty sands, in that order. Plate B-51 shows the gradation ranges of materials identified as type 1 (sands and borderline sands) and type 2 (silty sands and clayey sands). Materials, identified as type 3, are silts and clays that were found in the form of lenses and pockets deposited randomly throughout the foundation alluvium.

IN SITU DENSITIES

9-03 Undisturbed foundation sampling was conducted in 1975 (providing a total of 89 samples) and in 1980 (35 samples), from which dry densities were determined. The dam foundation soil logs show the sample location and density. A summary of the in situ tests is presented in table B-17.

Table B-17. In Situ Foundation Dry Densities.

Section	Elevation Range (ft, NGVD)				
	475-467	467-454	454-445	445-435	435-415
A	72.8 (9)	100.8 (30)	103.7 (26)	101.8 (20)	103.4 (10)
B	- - -	- - -	104.2 (5)	106.4 (4)	91.3 (2)
C	- - -	- - -	108.4 (4)	121.7 (1)	109.4 (1)
D	- - -	- - -	- - -	- - -	- - -
E	- - -	- - -	108.6 (4)	102.5 (1)	98.0 (1)
F	- - -	- - -	105.6 (3)	- - -	- - -
G	- - -	- - -	104.1 (3)	- - -	- - -
All Sections	72.8 (9)	100.8 (30)	104.7 (45)	103.2 (26)	101.8 (14)

NOTES: 72.8 = average dry unit weight in lb/ft^3.
(9) = number of values used to compute average.

9-04 The foundation soil borings indicate that clayey materials and silty sands are predominant above elevation 460 and that clean sands with increasing percentages of gravel and lenses of clayey silts become most predominant below. Field observations disclosed that undisturbed foundation material could only be obtained when the materials consisted of sands and silty sands with limited amounts of gravel. The average dry density data listed in table B-17 reflect the limitations of the undisturbed sampling program in that samples could only be obtained in materials without gravels.

STANDARD PENETRATION TESTS

9-05 Plots of corrected standard penetration test results, representing only the sands in the foundation, versus depth are shown on plate B-47. The penetration resistance is representative of materials which contain less than 12 percent plus No. 4 and 12 percent minus No. 200 materials by weight. The penetration resistance has been corrected to an effective overburden pressure of 1 ton/ft^2 (N_1) using the following equation:

$$N_1 = C_N N$$

where:

$C_N = 1 - 0.94 \log (\sigma_0' / \sigma_1')$,
σ_0' = effective overburden pressure in ton/ft^2 ,
$\sigma_1' = 1$ ton/ft^2.

The equation is shown graphically on plate B-47. Also shown on plate B-47 is the relationship of apparent relative density to corrected SPT values.

FOUNDATION PERMEABILITY AND GROUNDWATER

9-06 The Santa Ana River is a perennial stream from the vicinity of Riverside to Prado Dam and generally intermittent upstream and downstream of this reach. The piezometric surface upstream from the sheet pile cutoff stabilized at elevation 467 feet during investigations in May 1974. At the same time, the water table near the downstream toe of the dam was at elevation 443 feet, 24 feet lower than the piezometric surface upstream of the cutoff.

9-07 Piezometer water levels were measured monthly from January to July 1975. Perched water and confined aquifers were not detected in the foundation. The measured water surface elevations, shown on plate B-48, indicated an insignificant variation between the individual piezometers. The pump tests indicated the average permeability of the foundation to be approximately 280 ft/day (0.1 cm/sec).

BEDROCK

9-08 Bedrock contours beneath the dam (see pl. B-44) were developed from geologic mapping, foundation exploration prior to construction, construction data obtained during the installation of the sheet pile cutoff, and borings drilled to bedrock. These borings included the Becker drill holes, several bucket auger test holes, and the permeability test well. A detailed description of the bedrock underlying the dam embankment is presented in paragraph 2-06.

Outlet Works

GENERAL

9-09 The material types present along the proposed outlet works alinement consist of unconsolidated, cohesionless alluvial deposits overlying friable sandstone with siltstone and conglomerate interbeds. Based on detailed geologic mapping, and trenching and boring programs, Woodward-Clyde Consultants (1980) was able to delineate over 10 different Quaternary-age alluvial units in the project area for their Chino fault study. At least 5 of these units were identified during subsequent investigations for the proposed outlet works structures. The

bedrock, as mapped by Durham and Yerkes (1964), is identified as the Sycamore Canyon member of the Puente Formation. For testing and analytical purposes, the bedrock was divided into 4 distinct groups due to its heterogeneous nature. A discussion of the overburden and bedrock materials encountered during the field investigations is presented in the following paragraphs. The Prado Dam site geology mapped by Woodward-Clyde Consultants (1980) is presented on plates B-4 through B-7. The outlet works site geology, modified from plates B-4 through B-7, is depicted on plate B-52. A brief description of the mapped overburden and bedrock units identified by Woodward-Clyde Consultants (1980) is shown on plate B-4. A bedrock contour map for the left abutment area, developed from geologic mapping and field exploration programs, is presented on plate B-59. A geologic profile along the outlet works centerline is shown on plate B-60. Geologic cross sections depicting subsurface conditions at various stations along the outlet works alinement are shown on plates B-61 and B-62.

OVERBURDEN UNITS AND PROPERTIES

9-10 The overburden materials along the proposed outlet works alinement through the left abutment were classified based upon disturbed flight auger cuttings, rotary wash samples, bucket auger samples, and drilling action. A correlation with alluvial units identified by Woodward-Clyde Consultants (1980) was attempted. Most of the original surficial deposits in the left abutment area and in the abandoned Santa Ana River channel area downstream of the dam have been obscured or altered by past construction activities. These areas have been mapped as either artificial fill (af), disturbed undifferentiated surfaces (dus), or disturbed Quaternary alluvium (dqa).

9-11 The overburden materials along the alinement of the outlet works can generally be characterized as either older Quaternary alluvial (designated Qoal on pls. B-3 and B-60 through B-62) or Recent alluvial (designated Qal) deposits. The older alluvium overlies bedrock along the alinement from the approach channel to the stilling basin. The Recent alluvium comprises the remaining portion of the alinement downstream of the stilling basin. The older alluvium, which is confined to the left abutment area, consists of the following sequence: (1) a lower fluvial unit (Qo_2), representing coarse grained deposits of the Santa Ana River, (2) a paleosol or relict soil (So_1, So_2), which has developed on the fluvial unit, and (3) an eolian (windblown) silt (Qs) which overlies the soil. Younger terrace deposits (Qts), where present, appear to overlie the fluvial unit. The fluvial deposits, which comprise the majority of the alluvial materials in the left abutment area and rest directly on bedrock, range in thickness from 5 to 50 feet. The relict soil is typically 5 to 10 feet thick, while the upper layer of windblown silt is generally only 1 to 5 feet thick. The most extensive, undisturbed exposures of the older alluvium occur in cut slopes for the spillway and to a lesser extent in the prominent nose at the southwest end of the abutment. Exposures of low-lying terrace materials are restricted to the area north of the spillway forebay along the edge of the reservoir. Recent alluvial deposits in the project area

consist of lacustrine deposits (Qyl) in Prado Reservoir; and active stream deposits (Qys), which are exposed only in the existing downstream outlet channel but underlie the disturbed alluvium along the proposed outlet channel alinement downstream of the stilling basin. The thickness of the stream deposits, which overlie bedrock beneath the dam, appears to be at least 55 feet based on the geologic log of boring R83-12.

9-12 The older alluvium typically consists of gravelly silty sand/silty sand to sandy gravel with occasional thin lenses of silt/clayey silt and clayey sand. The coarser deposits are typically well graded, fine to coarse grained, loose to medium dense, and nonplastic. The finer lens deposits are typically medium to stiff and have low to medium plasticities. Cobble and boulder content within the older alluvium increases with depth, with boulder sizes up to at least 18 inches in diameter present in the unconsolidated lower portion of the fluvial unit. This so-called "basal conglomerate" overlies bedrock. During the field explorations, some caving was experienced in some sandy gravel and cobble layers occurring at shallow depths.

9-13 Downstream of the stilling basin along the alinement of the outlet channel, the Recent alluvium is typically silty sand and sand interbedded with sandy silt lenses. Some gravel up to 3 inches in diameter is present as are occasional cobbles up to 8 inches in diameter. The materials are typically poorly graded, fine to medium grained sand, loose to medium dense and nonplastic.

9-14 Subsurface investigations indicate that the overburden is typically 40 to 70-feet thick in the left abutment area, and reaches a maximum thickness of 76 feet in core boring C83-3. Along the proposed outlet works alinement, the maximum depth to the overburden/bedrock contact is inferred to be approximately 85 feet (elevation 490 feet), according to interpretation of the data from seismic refraction line RS83-4. Minimum overburden thicknesses are found in the area of the approach channel, and near the downstream end of the outlet conduits (see outlet works geologic profile on pl. B-60). The overburden materials reach known depths of 90 feet under the dam embankment and approximately 55 feet in the transition area between the stilling basin and downstream outlet channel.

BEDROCK UNITS AND PROPERTIES

9-15 The bedrock along the proposed outlet works alinement is the Sycamore Canyon member of the Tertiary-age Puente Formation (Tpsc). The rock (primarily the coarser sandstone and pebbly sandstone layers) outcrops in scattered areas of the left abutment surface: in the prominent nose at the southwest end of the abutment and to a lesser extent on the southeast side in the spillway excavation, and on the northwest facing slope downstream from the dam. Bedrock exposures on the upstream side of the abutment, as shown on plate B-52, are rather indistinct. Subsurface borings indicate that the average bedrock elevation in the abutment area is 510 feet. The bedrock surface is an old erosional surface exhibiting known local relief of up to at least

23 feet. However, the geologic profile along the proposed outlet works centerline, which was developed from bedrock contours and foundation exploration data, indicates that the bedrock surface may exhibit local relief of up to 40 feet. Erosion and to a lesser extent construction activities are the major reasons for this extreme irregularity. The minimum bedrock elevation at the left abutment determined from drilling was approximately 496 feet in boring C83-3, and according to results of the seismic refraction surveys, the overburden/bedrock contact may be even lower along the proposed alinement. A bedrock elevation of 490 feet was inferred at the north end of survey line RS83-4, near station 15+00. The shallow bedrock surface beneath the left abutment drops off rapidly to unknown depths upstream under Prado Reservoir and downstream toward the active stream channel, as depicted on plate B-60. The approximate bedrock surface drops below invert elevation within the upper portion of the approach channel excavation. Downstream from its surface contact on the southwest face of the left abutment, the bedrock surface steepens abruptly, dropping below invert elevation within the lower portion of the stilling basin excavation. Bedrock was not encountered during explorations for the downstream outlet channel.

9-16 The bedrock at the left abutment shows signs of subaerial weathering at the overburden contact and the overlying basal conglomerate occasionally contains fragments of weathered sandstone and siltstone. The general properties of the Sycamore Canyon member can be observed in outcrops and shallow trenches in the vicinity of the abutment, but along the alinement itself, the nature of the bedrock can be determined only from extruded Pitcher samples and recovered rock cores. During the laboratory testing of the undisturbed samples, the bedrock was categorized into four distinct groups, A-B, C, D, and E, based upon grain-size distribution and physical appearance. Laboratory tests were conducted on representative samples from each group, which had been obtained from different elevations within selected bore holes. A detailed description of each group can be found on plate B-53. Placing the bedrock into only four groups has its limitations since contacts between the various layers or subunits tend to be gradational and materials intermediate in composition between the groups as defined are undoubtably present and likely to be encountered during excavation. Nonetheless, the four groups do provide an adequate method for representing the different lithologic characteristics of the bedrock materials.

9-17 In general, the bedrock grades between silty sandstones and sandy siltstones. The coarsest and "cleanest" sandstones contain at least 15 percent silt and clay binder and the finest siltstones contain at least 20 percent sand. Using the Unified Soils Classification System (ASTM D 2487), the bedrock materials can generally be described as silty sands (SM) and sandy silts (ML). Table B-18 presents the results of mechanical analyses of both overburden and bedrock samples from the rotary borings. Bedrock group A-B, classified as a sandstone, is characterized by well graded, fine- to coarse-grained sand in a 15 to 25 percent low plastic silt-clay matrix. Group A-B materials are more prevalent on the downstream half of the abutment and are locally conglomeratic, with layers of up to 50 percent rounded pebbles to 3-inch

observed maximum diameter. Bedrock group C, classified as a sandy siltstone to silty sandstone, is characterized by moderately well graded, fine- to medium-grained sand in a 35 to 55 percent low plastic silt matrix. Bedrock group D, a sandy siltstone, consists of mostly very fine grained sand in a greater than 60 percent low plastic silt to borderline silt-clay matrix. Bedrock group E, also classified as a sandstone, consists of mostly fine grained sand in a 25 to 35 percent low plastic silt matrix. All bedrock groups are typically very dense but generally uncemented. Calcium carbonate (CaCO$_3$) cementation is spotty and only occasionally appears to be layered. Laboratory soils tests conducted in 1983 on undisturbed samples from each bedrock group indicate the materials are strong. Shear strength and cohesion values, selected from interpretations of consolidated undrained triaxial compression test data, with pore pressure measurements used to determine consolidated drained values (R-type test), are shown on plate B-82. Results of the 1983 unconfined compression tests are shown in table B-19. Higher compressive strengths determined for group C and group E materials may reflect a certain degree of cementation in the particular sample tested. The coherency of all bedrock types (except cemented zones) when wet is very poor and intact samples disintegrate when immersed in water. In 1971, unconfined compression tests were conducted by SPD Laboratory on five sandstone and siltstone cores from the spillway forebay area. The soft, friable, porous sandstone samples had compressive strengths ranging from 1.0 to 3.2 ton/ft^2 while the moderately hard, slightly porous siltstones had compressive strengths of 14.4 and 19.6 ton/ft^2.

Table B-18. Outlet Works - Mechanical Analyses of Rotary Boring Samples.

Sample No.	Hole No.	Mechanical Analysis Depth (ft) from	to	Percent Finer #4	#40	#200	LL	PI	Bedrock Group
1	1	25.0		58	21	5			
2		40.0		80	28	9			
3		53.7	54.0	70	25	8			
4		79.5	80.2	100	72	24			E
5		88.9	91.1	100	80	42	31	5	C
6		112.0	113.0	100	85	53	32	3	C
7		129.9	130.5	100	84	36			E
8	2	11.0	15.0	57	33	20			
9		20.0	25.0	81	25	13			
10		30.0	35.0	83	26	10			
11	3	2.5	10.0	100	91	71			
12		47.9	48.0	33	14	4			
13		51.2	51.6	49	10	3			
14		54.1	55.7	74	35	3			
15		60.5	60.9	72	56	27			

Table B-18. (Continued)

		Mechanical Analysis							
Sample	Hole	Depth (ft)		Percent Finer					Bedrock
No.	No.	from	to	#4	#40	#200	LL	PI	Group
16		66.0	66.8	86	49	19			A-B
17		89.5	90.3	97	52	17			A-B
18		99.5	100.4	98	46	16	31	7	A-B
19		137.5	138.3	97	55	21			A-B
20	4	5.0	8.5	99	89	68			
21		8.5	16.5	58	32	20			
22		16.5	20.0	82	29	16			
23		72.6	72.8	87	49	17			A-B
24	5	53.3	53.8	100	68	25			E
25	7	12.0	15.0	77	35	15			
26		21.0	25.0	63	38	14			
27		35.9	38.2	100	98	78	36	8	D
28		55.2	56.3	100	99	82	40	15	D
29		59.3	59.9	100	98	44			C
30		74.4	76.2	99	85	25			E
31		83.5	84.1	100	99	66			C
32		94.7	95.2	100	99	23			E
33		96.3	97.4	100	99	23			E
34	8	43.0	44.0	100	62	37			
35	9	33.2	34.5	99	55	22			A-B
36		46.5	46.7	60	28	12			A-B
37		51.3	52.8	45	28	10			A-B
38		65.0	66.0	96	58	29	39	17	A-B?
39	10	25.0	30.0	100	59	32			
40		37.0	37.5	54	26	9			
41		39.0	39.5	97	67	22			A-B
42	11	6.0	7.5	100	68	33			E
43	12	55.2	56.0	100	50	15			A-B
44	14	42.0	43.4	93	47	19			A-B
45	15	30.7	31.5	97	65	27			A-B
46	16	53.5	54.6	100	69	37	31	4	C
47		74.0	74.3	100	60	18			A-B
48		95.5	96.9	96	73	55	34	5	C
49	17	30.0	51.0	98	37	6			
50		51.0	55.0	82	22	3			
51	18	48.2	48.7	100	93	31			E
52		86.8	87.0	100	97	65			C
53		91.5	93.3	100	72	25			E
54		101.0	102.3	100	99	60			C
55		126.5	127.3	100	77	39	27	3	C

Table B-19. Outlet Works - Summary of Unconfined Compressive Strength Test Results.

Hole No.	Bedrock Group	Depth (ft) from	Depth (ft) to	Unconfined Compressive Strength (ton/ft^2)
R83-1	E	129.9	130.5	12.8
R83-3	A-B	137.5	138.3	1.1
R83-7	D	55.2	56.3	1.0
R83-18	C	126.5	127.3	5.6

9-18 Although the strike and direction of dip can only be inferred from nearby outcrops, it appears that the bedrock along the proposed outlet works alinement strikes towards the northwest (normal to the proposed centerline) and dips steeply upstream (45 to 80 degrees). No positive evidence of the axis of the Arena Blanca syncline, as projected on plates B-4 and B-5, was discovered during the field investigations. The contacts between the different bedrock layers are generally indistinct and gradational, making any positive identification of the syncline difficult. Occasionally, very thin clay seams with slickensides are found along planar contacts. Joints within the rock mass are very widely spaced and appear to be randomly oriented. Laboratory permeability test values on selected rock cores ranged from 1×10^{-1} to 5×10^{-3} ft/day. A summary of field permeability tests conducted during the 1971 investigations for the previously proposed spillway alternatives is presented in table B-20.

Table B-20. Summary of Field Permeability Tests.

Hole No.	Interval Tested from (ft)	Interval Tested to (ft)	Hole Diameter (in)	Gauge Pressure (lbs/in^2)	Flow (gal/min)	Rock Mass Permeability (ft/day)
DD-52	25.1	48.1	8	10	0.15	1.4×10^{-2}
				20	0.15	1.0×10^{-2}
	26.5	70.2		20	0.52	1.9×10^{-2}
DD-53	49.0	99.3	6	20	0.18	5.0×10^{-3}
DD-54	18.9	73.9	8	20	0.02	6.0×10^{-4}
DD-55	64.5	180.3	6	5	1.5	1.8×10^{-2}
				10	3.0	3.3×10^{-2}
				20	6.0	5.8×10^{-2}
DD-56	5.0	71.0	8	0	0.26	1.7×10^{-2}

GROUNDWATER

9-19 A piezometric profile along the proposed outlet works alinement, developed from water levels measured in the observation wells and encountered in the bucket auger test holes during the period of March-April 1987, is depicted on the geologic profile on plate B-60. It appears that groundwater will be encountered throughout the outlet works excavation with the possible exception of that portion of the downstream outlet channel near the stilling basin. The static water levels measured in the left abutment observation wells (see compilation in table B-12) indicate that most of the bedrock is probably saturated. The groundwater table is near the overburden/bedrock contact along much of the alinement, see plate B-60. Reservoir ponding is apparently the main source for the water and it appears that the concrete keywall and core trench backfill between the dam and spillway causes the piezometric surface to be somewhat higher on the upstream side. Water levels respond very slowly to changes in the reservoir pool elevation since the bedrock is only slightly permeable.

FAULTING

9-20 An attempt was made during the field investigations to locate more precisely the trace of the Chino fault in proximity to the left abutment and the proposed outlet works alinement. Explorations conducted by Woodward-Clyde Consultants (1980) north of the spillway forebay (trenches T7 and T15 and rotary borings B6 and B7) failed to define the nature of faulting at those locations. However, information obtained was used to construct a generalized cross-section (section 1 on plate B-10) across the Chino fault. Since the fault is characterized by noticeable changes in bedrock elevation along its trace, rotary borings R83-8, R83-9, R83-10, and R83-15 were drilled near the site of previous explorations, but to the west of the suspected fault trace, as shown on plate B-52. The drilling indicated the following: (1) increasing differences in bedrock elevation toward the fault along the line of closely spaced borings, from elevation 492 feet in R83-9 to elevation 476+ feet in R83-8, which is in very close agreement with section 1 on plate B-10, and (2) a relatively high bedrock elevation of 499 feet in boring R83-15, which is only 50 feet from the projected fault trace. The irregular subsurface bedrock configuration may be more the result of localized erosion prior to deposition of the older alluvium than to faulting. The high bedrock elevation in boring R83-15 makes it unlikely that the major trace of the Chino fault is located southwest of this point. Thus, it appears that the Chino fault crosses the proposed outlet works alinement in the area of the approach channel excavation as shown on plate B-52.

EXCAVATIONS

9-21 The geologic profile along the proposed outlet works alinement (see pl. B-60) and geologic cross sections drawn at selected stations (see pls. B-61 and B-62) indicate that bedrock excavation will be necessary to construct the approach channel, tower, outlet conduits, and

stilling basin. The tower and outlet conduits will be founded entirely on bedrock. The majority of the approach channel invert downstream of station 5+00 will be on bedrock. However, the irregularity of the bedrock surface along the channel alinement will result in a greater amount of bedrock excavation on the left side of the channel, see cross sections at stations 6+10 and 7+50 on plate B-61. Likewise, most of the stilling basin will be founded on bedrock, but the west-northwest sloping bedrock surface will also result in increased bedrock excavation on the left side downstream of station 18+00 (see pl. B-62). The downstream outlet channel will be founded entirely on alluvial materials.

9-22 The results of the field exploration and laboratory testing programs indicate that the required overburden and bedrock excavation for the proposed outlet works relocation through the left abutment can be effectively accomplished by mechanical means. The majority of the overburden materials consist of cohesionless sands, gravels, cobbles, and some boulders. The bedrock is relatively soft and generally uncemented and is represented by subsurface P-wave velocities ranging from 5285 to 7700 ft/sec. The wide range in velocities can be attributed to changes in lithology and the degree of cementation of the bedded sediments. Both the overburden and bedrock materials encountered could probably be excavated with conventional earthmoving equipment, though light to heavy ripping may be required locally to facilitate excavation of harder, more cemented zones in the bedrock. During the 1983 field exploration program, the concrete keywall, installed between the left abutment of the dam and the spillway, was encountered at an approximate elevation of 516 feet in rotary boring R83-6. This 3-foot wide by 15-foot high structure crosses the proposed outlet works alinement at approximately station 12+10. The approximate location of the keywall is shown on plate B-59 and a geologic cross section at station 12+10 is shown on plate B-61.

SLOPE STABILITY

9-23 Since the overburden materials are characterized by unconsolidated, cohesionless sands, gravels, cobbles, and occasional boulders, relatively flat temporary cut slopes would be necessary to ensure stability during construction. Slopes steeper than 1V on 1.5H should not be permitted. Slopes in the bedrock could be steeper. The permanent slopes downstream from the spillway have stood for over 45 years at 1V on 1H, and temporary slopes at the right abutment and spillway were established at 4V on 1H during construction. However, these slopes were successfully cut under dry conditions and the slopes for the outlet works excavation at the right abutment required shotcrete to prevent air slaking of the siltstone interbeds. Since the majority of the low permeability left abutment bedrock appears to be saturated, the slopes would remain wet during construction and might lose a significant amount of strength unless remedial measures such as a dewatering system or shotcrete application were implemented. Slaking would appear to have a greater adverse impact on slope stability than the bedrock structure itself. The favorable orientation of the beds and

the infrequency of jointing in the rock mass would make bedding plane or wedge failures less likely than sloughing of the bedrock materials upon exposure to air or water.

Dikes

AUXILIARY DIKE

9-24 The auxiliary dike foundation consists of clayey sand and sandy clay (SC/CL) underlain by silty gravelly sand (SM). The clayey sand/sandy clay layer varies in thickness from 7 feet thick near the spillway (approximate sta. 69+00) to 15 feet at approximately station 50+50. The materials are described as brown, dry to moist, dense to hard with SPT blow counts ranging from 15 to refusal and typically between 30 and 35 blows/ft. The silty gravelly sand materials are light brown, damp, medium to dense with SPT blow counts ranging from 15 to 60+ and averaging 35 blows/ft. Groundwater was not encountered during explorations for the proposed dike.

DIKE AT ALCOA ALUMINUM PLANT

9-25 The foundation along the alinement of the dike at the Alcoa Aluminum Plant is divided into two areas. Along Rincon Street between stations 10+00 and 52+00, the foundation consists of brown silty gravelly sands (SM) and sands (SP) with a 5-foot layer of clayey sand (SC) approximately 16 to 23 feet below the ground surface. The silty gravelly sand is loose to medium dense, with SPT blow counts from 8 to 19 and an average of 13 blows/ft. The materials increase in coarseness with depth and are sandier and looser between stations 49+00 and 52+00. Along Smith Avenue between stations 52+00 and 60+50, the foundation consists of a 22 to 27-foot thick layer of reddish brown sandy clay (CL) underlain by a brown silty gravelly sand (SP-SM). Groundwater was encountered at elevation 533 feet, approximately 11 feet below ground surface. The sandy clay is medium stiff above the water table with SPT blow counts ranging from 0 to 16 with an average of 8. Below the water table, the sandy clay is very soft to soft, with SPT blow counts ranging from 0 to 6 with an average of 3 blows/ft.

DIKE AT CALIFORNIA INSTITUTION FOR WOMEN

9-26 Part of the proposed dike at the California Institution for Women is located in an agricultural field/pastureland. Between stations 10+00 and 30+00, the foundation on the reservoir-side of centerline consists of loose silt and organic silt (MH/OH) to 12-foot depths. Landward from the centerline, the foundation consists of a stiff, sandy clay (CH) to 17-foot depths. These materials are underlain by loose to medium dense, sandy clay-sandy silt (CL-ML) and clays (CH). Since investigations were limited, it was assumed that the foundation between stations 30+00 and 72+30 was stiff, sandy clay (CH). Groundwater was not encountered during explorations for the proposed dike but is estimated to be approximately 65 feet below ground surface (elevation 505 feet).

DIKE AT CORONA SEWAGE TREATMENT PLANT

9-27 The foundation for the dike at the Corona Sewage Treatment Plant consists of a 16 to 25-foot layer of stiff, clayey sand/sandy clay (SC/CL) underlain by sandy gravels (GP) and silty gravelly sands (SM). Groundwater was encountered at an approximate depth of 10 feet below ground surface.

DIKE AT CORONA EXPRESSWAY

9-28 The material types present along the proposed dike alinement consist of Quaternary-age alluvial deposits and Tertiary-age sandstone bedrock. Artificial fill, consisting of engineered earthfill and paved roadway, is present along the existing Corona Expressway. Bedrock exposures in the Chino Hills along the western edge of the Prado Dam reservoir area generally occur above elevation 520 feet (see pls. B-3 and B-6). Below the bedrock contact, increasing thicknesses of alluvial materials are anticipated as the bedrock surface drops off to the east beneath the reservoir area. Along the proposed dike, the maximum overburden section would occur beneath the toe of the slope on the reservoir side. There, the alluvial materials could reach thicknesses of between 25 and 30 feet, depending on the actual bedrock slope configuration (see pl. 15 of the Main Report, Volume 2). The bedrock surface is assumed to maintain an average 1V on 3H slope from its surface contact below the existing highway to a depth in the adjacent reservoir area at least equal to that encountered under the dam embankment (90 feet, elevation 380 feet).

9-29 The older alluvial materials, which are generally poorly bedded sands, gravels, and silts mantle the gentler hillside slopes and reach a known thickness of 5 feet, according to the geologic log of core hole DD-56. Limited exposures of Recent alluvial materials, consisting mainly of loose sands and gravels, fill some of the small active hillside washes and have a thickness of at least 10 feet as indicated in core hole DD-55.

9-30 The bedrock consists mainly of a white, soft, medium to coarse grained, friable, and weakly cemented sandstone, which appears to be representative of the possibly Pliocene-age upper portion of the Sycamore Canyon member of the Puente Formation. The bedrock contains occasional layers and lenses of a more conglomeratic sandstone. The zone of soft bedrock extends to a depth of 62 feet in core hole DD-55, drilled near the crest of a hill overlooking the roadway, and to a bottom depth of 71 feet in core hole DD-56, drilled adjacent to the existing roadway. Underlying the soft sandstone in core hole DD-55 is a moderately hard sandstone with zones containing from 10 to 30 percent pebble-size clasts. The foundation rock is characteristically massive, with only scattered jointing, thin shears and indistinct bedding noted. Core recovery was very good, approximately 89 percent, in the harder more competent sandstone encountered in core hole DD-55, while the softer, highly erodible sandstone common to both holes resulted in much poorer core recovery, averaging 31 percent. The bedrock in both core

holes is relatively impermeable, with calculated rock mass permeabilities ranging from 1.8×10^{-2} to 5.8×10^{-2} ft/day for the 116-foot interval tested in hole DD-55 and 1.7×10^{-2} ft/day for the 66-foot interval tested in hole DD-56. Groundwater was not encountered during explorations for the proposed dike.

X. LABORATORY TESTS AND RESULTS

General

10-01 Laboratory tests, consisting of mechanical analyses, Atterberg limits and moisture content determinations, compaction, unconfined compression, permeability, swell, static and cyclic triaxial compression, resonant column and consolidation, were conducted in general accordance with EM 1110-2-1906, "Laboratory Soils Testing," dated November 1970. Maximum-minimum density tests were determined in accordance with ASTM D 2049-69 (dry method). Materials were classified in accordance with the Unified Soils Classification System.

Dam Embankment and Foundation

10-02 Static and dynamic tests were conducted on existing embankment, foundation, and potential embankment (borrow area no. 1) materials by the South Pacific Division (SPD) Laboratory in January 1973, between June 1975 and June 1976, and between March 1980 and April 1981. Dynamic tests were conducted by Converse Davis Dixon Associates between April and July 1975 on foundation and existing embankment materials. Static and dynamic laboratory tests and results for the foundation, existing embankment, and borrow materials are summarized in the following paragraphs.

STATIC SHEAR TESTS

10-04 To obtain material properties of the existing embankment and foundation for static slope stability and two-dimensional finite element analysis, consolidated-undrained triaxial shear tests with and without pore pressure measurements ($\bar{R}$-tests and R-tests), consolidated-drain triaxial shear tests (S-tests), and direct shear tests (DS-S) were conducted on remolded and undisturbed samples. A summary of the test conditions and shear test results in terms of shear strengths is presented in table B-21 and plate B-83.

Table B-21. Static Shear Strengths.

Material	γ_{di}	γ_{dc}	Test	R-strengths		S-strengths		σ_3	$(\sigma_1 - \sigma_3)$ max	Remarks
	(lb/ft^3)	(lb/ft^3)		(deg)	(ton/ft^2)	(deg)	(ton/ft^2)	(ton/ft^2)	(ton/ft^2)	
Pervious	121.5	-	R	32.5	0.80	36.0	0	2.00	7.55	SC-SM, remolded 95%RC
								4.03	12.56	SC-SM, remolded 95%RC
								6.03	20.59	SC-SM, remolded 95%RC
	117.9	-	DS-S	-	-	36.5	-	-	-	SC-SM, remolded 95%RC
	119.4	-	DS-S	-	-	36.5	-	-	-	SC, remolded 95%RC
Random	121.9	-	R	15.5	0.25	35.0	0	1.00	1.34	SC, remolded 95%RC
								2.00	1.44	SC, remolded 95%RC
								4.00	3.66	SC, remolded 95%RC
Core	117.3	-	R	15.0	0.10	31.5	0	2.00	1.70	SC, remolded 95%RC
								4.00	3.17	SC, remolded 95%RC
								6.00	4.65	SC, remolded 95%RC
	116.3	-	DS-S	-	-	34.5	0	-	-	SC, remolded 95%RC
	116.3	-	R	15.0	0.80	-	-	1.08	2.87	SC, undisturbed
								2.16	3.50	SC, undisturbed
Foundation	109.9	113.8	S			40.0	0	0.50	1.98	SW, remolded 38%Dr
	112.2	115.4	S			38.5	0	0.50	2.18	SW, remolded 50%Dr
								1.50	4.86	SW, remolded 50%Dr
								3.00	10.56	SW, remolded 50%Dr
	114.3	116.1	S			39.5	0	0.50	2.46	SW, remolded 60%Dr
								1.50	4.70	SW, remolded 60%Dr
	118.6	119.2	S			41.0	0	0.50	2.80	SW, remolded 60%Dr
								1.50	6.74	SW, remolded 80%Dr
								3.00	12.53	SW, remolded 80%Dr
								5.00	19.38	SW, remolded 80%Dr
	102.1	103.7	S			42.0	0	0.72	3.08	SW, remolded 80%Dr
	103.5	106.5	S			39.5	0	2.16	7.45	SW-SM, undisturbed
	104.9	107.1	S			42.0	0	2.16	8.31	SW-SM, undisturbed
	116.7	119.5	S			45.0	0	2.16	10.80	SW, undisturbed
	113.8	114.6	S			42.0	0	2.88	12.69	SW-SM, undisturbed
	104.9	108.9	S			41.5	0	4.32	16.62	SW-SM, undisturbed
	106.3	109.9	S			39.5	0	4.32	14.62	SW-SM, undisturbed

*RC = Relative Compaction. **Dr = Relative Density.

DYNAMIC LABORATORY TESTS

10-05 A summary of the cyclic triaxial tests is presented in table B-22. The resonant column and strain-controlled cyclic triaxial test results are summarized on plate B-85 as variation of damping ratio and shear modulus with strain for the various existing embankment and foundation materials.

10-06 The cyclic triaxial shear tests were conducted on undisturbed samples obtained from samples frozen in Shelby tubes. The frozen samples were allowed to thaw slightly to facilitate extrusion and cutting into 6-inch lengths. After cutting, the samples were refrozen and handled in a frozen condition to minimize disturbance during preparation for testing. After sample preparation, the samples were allowed to thaw completely in the triaxial cell under a small confining pressure. The samples were saturated and consolidated for cyclic triaxial tests at K_c ratios of 1.0, 1.5, and 2.0 with varying confining pressures. A summary of the test results is presented in table B-23. The cyclic triaxial tests were conducted to obtain cyclic shear strength data for the analysis. The SPD test results also clarified possible sample disturbance of samples tested by Converse Davis Dixon Associates. The comparison is discussed in detail in paragraph 14-28.

Borrow Area No. 1

10-07 Modification of the Prado Dam embankment and construction of the auxiliary dike, and the dikes at the Alcoa Aluminum Plant, Sewage Treatment Plant, and Corona National Housing Tract will utilize materials from borrow area no. 1. Representative samples were obtained from borrow area no. 1 to determine static embankment fill engineering properties. The samples were graded into Zone I and Zone II materials and remolded for detailed testing.

STATIC SHEAR TESTS

10-08 The Zone II samples were selectively blended to obtain gradations representative of the fine quartile and mean gradations of the blended Zone II borrow materials.

10-09 The Zone I samples were selectively blended to obtain gradations representative of the mean gradation of the blended pervious borrow materials.

10-10 The results of the static tests are summarized in table B-24 and plate B-84. The results of the shear tests were used to obtain material shear strength parameters for slope stability analysis and Young's Modulus (E) from stress-strain relationships for use in a two-dimensional finite element analysis.

TABLE B-22. Summary of Cyclic Triaxial Tes

Test No.	as Tested	Kc	(lb/in^2) σ_1	σ_3	σ_{dp}	$\frac{\sigma_{dp}}{2\sigma_{3c}}$	Cycles @ X% Strain X=2	X=5	X=10	Reason for Data Exclusion
Pervious Zone										
1	117.3	1.0	15	15	7.5	0.25	50	160	00	
2	113.8	1.0	15	15	10.5	0.35	31	56	300	
3	114.0	1.0	15	15	13.5	0.45	11	25	40	
4	112.2	1.0	30	30	15.0	0.25	2	4.8	11	
5	117.8	1.0	30	30	12.0	0.20	4	8.8	24	
6	122.7	1.0	30	30	9.0	0.15	0.15	0.0	0.0	
6A	122.7	1.0	30	30	16.0	0.27	2.5	53	75	Rerun of test 16
42X	114.5	1.0	30	30	18.0	0.30	5.8	14	46	
76X	110.8	1.0	30	30	24.0	0.40	18	53	180	
7	118.6	1.0	60	60	24.0	0.20	7	15	46	
8	124.7	1.0	60	60	18.0	0.15	00	00	00	
8A	124.7	1.0	60	60	36.0	0.30	17	47	160	Rerun of test 8
9	119.5	1.0	60	60	42.0	0.35	3	85	31	
43X	120.9	1.0	60	60	33.4	0.27	4	11	29	
51	121.4	1.5	22.5	15	12.0	NA	22	33	46	
52	121.0	1.5	22.5	15	15.0	NA	25	39	60	
87X	117.4	1.5	22.5	15	17.0	NA	6.2	19	42	
55	120.4	1.5	45	30	27.0	NA	20	34	54	
56	119.1	1.5	45	30	32.5	NA	1.2	6.3	23	
53	120.9	2.0	30	15	10.5	NA	00	00	00	
53A	120.8	2.0	30	15	15.0	NA	00	00	00	Rerun of test 53
53B	120.8	2.0	30	15	21.0	NA	18	34	68	Rerun of test 53A
54	116.3	2.0	30	15	23.2	NA	2.2	4.8	8.5	
88X	115.6	2.0	30	15	16.0	NA	32	41	54	
57	119.3	2.0	60	30	37.7	NA	1.7	6.2	12	
58	120.0	2.0	60	30	33.0	NA	10	19	28	
Random										
16	122.8	1.0	15	15	7.3	0.24	4.6	12	37	
18	124.9	1.0	15	15	10.5	0.35	19	44	110	
19	122.8	1.0	15	15	4.5	0.15	00	00	00	
19A	122.8	1.0	15	15	9.0	0.30	24	44	74	Rerun of test 19
41X	121.6	1.0	15	15	11.5	0.38	3.1	6.8	12	
20	120.5	1.0	30	30	15.0	0.25	10	16.5	24	
22	121.4	1.0	30	30	18.0	0.30	5	9.6	19	
24	119.5	1.0	30	30	12.0	0.20	35	73	130	
25	113.8	1.0	60	60	30.0	0.25	8.4	18	34	
26	120.8	1.0	60	60	24.0	0.20	29	55	96	
27	118.2	1.0	60	60	42.0	0.35	3	7.5	16	
64	124.2	1.5	22.5	15	12.0	NA	18	33	54	
67	114.9	1.5	22.5	15	15.0	NA	1.6	7.5	16	
69	118.5	1.5	45	30	24.8	NA	1.4	3.1	5.8	
70	128.2	1.5	45	30	18.0	NA	63	88	125	
86X	115.4	1.5	45	30	28.0	NA	1.4	5.5	14	
84	116.0	1.5	90	60	48.0	NA	1.1	4.2	10.5	
85	127.4	1.5	90	60	47.6	NA	3.2	8	17	

Test No.
Core Z
10
11
12
40X
13
14
15
47X
17
21
23
39X
50
71
Founda
28
29
29A
30
45X
46X
48X
49X
82X
37
38
83X
32
34
35
81X
31
33
36
44X
60
61
59
62
63
68
65
66

Note:

of Cyclic Triaxial Test Results on Undisturbed Materials. (1975)

Reason for Data Exclusion	Test No.	as Tested	Kc	(lb/in^2)			$\frac{\sigma_{dp}}{2\sigma_{3c}}$	Cycles @ X% Strain			Reason for Data Exclusion
				σ_1	σ_3	σ_{dp}		X=2	X=5	X=10	
	Core Zone										
	10	116.5	1.0	15	15	4.5	0.15	110	175	260	
	11	116.4	1.0	15	15	9.0	0.30	7	13	28	
	12	113.9	1.0	15	15	6.0	0.20	370	450	480	
	40X	118.3	1.0	15	15	12.0	0.40	8	40	180	
	13	122.1	1.0	30	30	18.0	0.30	25	58	80	
	14	120.0	1.0	30	30	24.0	0.40	16	45	72	
un of test 16	15	106.7	1.0	30	30	27.0	0.45	0.3	0.7	1.9	
	47X	112.0	1.0	30	30	24.8	0.43	2	4.3	7.2	
	17	125.5	1.0	60	60	48.0	0.40	5.5	19	55	
	21	120.5	1.0	60	60	36.0	0.30	60	140	310	
	23	115.2	1.0	60	60	37.9	0.32	2.7	5.4	8.8	
un of test 8	39X	111.9	1.0	60	60	42.7	0.36	0.6	1.8	3.2	
	50	119.5	1.5	45	30	24.0	NA	2.5	15	50	
	71	124.5	1.5	45	30	18.0	NA	40	117	290	
	Foundation										
	28	119.6	1.0	10	10	4.0	0.20	22	29	39	69% Gravel
	29	108.9	1.0	10	10	3.0	0.15	00	00	00	
	29A	108.9	1.0	10	10	6.0	0.30	25	33	50	Rerun of test 29
	30	115.9	1.0	10	10	5.0	0.25	25	37	58	
	45X	97.7	1.0	10	10	5.0	0.25	12	18	41	
un of test 53	46X	96.2	1.0	10	10	5.7	0.29	10	18	51	
un of test 53A	48X	89.4	1.0	10	10	6.6	0.33	3.0	7.7	19	Sandy silt, ML
	49X	98.2	1.0	10	10	7.2	0.36	2.7	4.7	17	
	82X	101.1	1.0	10	10	8.0	0.40	3.0	7.5	25	
	37	110.8	1.0	10	10	4.0	0.20	13.5	30	110	
	38	114.5	1.0	10	10	6.0	0.30	12	35	160	
	83X	99.2	1.0	10	10	7.9	0.40	4.5	14	50	
	32	105.4	1.0	30	30	15.0	0.25	18	30	45	
	34	105.0	1.0	30	30	12.0	0.20	36	78	140	
	35	106.0	1.0	30	30	18.0	0.30	8	21	42	
n of test 19											
	81X	104.5	1.0	30	30	24.0	0.40	2	7.2	25	
	31	105.6	1.0	60	60	30.0	0.25	3	5.5	8	
	33	107.2	1.0	60	60	18.0	0.15	75	92	120	
	36	114.8	1.0	60	60	23.3	0.20	12.8	17	21	
	44X	105.8	1.0	60	60	30.0	0.25	5.2	11	14	
	60	114.9	1.5	15	10	6.0	NA	15	25	43	
	61	114.7	1.5	15	10	8.0	NA	4	8.6	17	
	59	109.2	1.5	45	30	23.9	NA	1.6	3.4	5.8	
	62	118.0	1.5	45	30	18.0	NA	17	21	25	31% Gravel
	63	92.8	2.0	20	10	8.0	NA	15	59	190	
	68	91.8	2.0	20	10	11.2	NA	2.3	4.2	7	
	65	96.5	2.0	60	30	30.0	NA	1.3	5.6	19	
	66	107.8	2.0	60	30	24.0	NA	40	235	00	

Note: One-half double amplitude axial strain for isotropic tests.
Zero to peak compressive axial strain for anisotropic tests.

Table B-23. Summary of Cyclic Triaxial Test Results (1981).

Test No.	$\gamma_{as\ tested}$	K_c	σ_1	σ_3	σ_{dc}	$\sigma_{dc}/2\sigma_{3c}$	Cycles @ X% Strain (da)	
	(lb/ft³)			(ton/ft²)			X=5	X=10
Foundation								
74097A	104.4	1.5	1.08	0.72	0.86	0.60	13	34
74097B	97.4	1.0	1.00	1.00	0.50	0.25	5	6
74d98	94.2	1.0	2.50	2.50	1.00	0.20	16	-
74099	103.4	1.0	5.00	5.00	2.00	0.20	34	
74100	106.0	2.0	4.32	2.16	5.62	1.30	4	13
74101	93.0	1.0	5.00	5.00	2.00	0.20	7	10
74102	105.8	1.5	1.08	0.72	0.72	0.50	180	220
74103A	109.0	1.0	2.50	2.50	1.25	0.25	2	4
74103B	99.4	1.0	2.50	2.50	1.50	0.30	6	11
74104A	100.6	2.0	1.44	0.72	1.01	0.70	500+	
74104B	103.3	1.0	1.00	1.00	0.50	0.25	-	
74105A	104.5	1.0	5.00	5.00	2.00	0.20	66	120
74105B	101.8	1.5	6.48	4.32	3.20	0.37	40	
74105C	103.0	2.0	4.32	2.16	2.59	0.60	140	430
74106A	97.0	1.5	1.08	0.72	0.58	0.40	56	64
74106B	114.7	1.5	6.48	4.32	2.60	0.30	15	20
74107	93.4	1.0	5.00	5.00	2.50	0.25	10	15
74108	101.7	1.0	1.00	1.00	0.50	0.25	9	11
74109A	111.6	1.5	3.24	2.16	1.80	0.42	21	45
74109B	110.1	1.5	1.08	0.72	0.43	0.32	36	48
74110A	88.2	1.0	2.50	2.50	1.25	0.25	46	56
74110B	81.7	1.0	1.00	1.00	0.60	0.30	180	200
74112A	107.4	1.0	1.00	1.00	0.60	0.70	6	11
74112B	99.2	1.0	1.00	1.00	0.70	0.35	1	4
74113	75.2	1.0	1.00	1.00	0.70	0.35	1	2
74114	87.3	1.5	6.48	4.32	4.32	0.50	2.5	5.4
74115A	99.2	1.0	1.00	1.00	0.70	0.35	24	28
74115B	101.2	2.0	1.44	0.72	1.14	0.80	66	130
74115C	104.0	1.0	2.50	2.50	1.75	0.35	no results	
74116	107.5	1.5	6.48	4.32	3.84	0.45	11	22
74117	98.1	1.0	5.00	5.00	2.00	0.20	-	
7F118	97.5	1.0	2.50	2.50	1.50	0.30	5	11
74119A	92.9	2.0	8.64	4.32	5.19	0.60	10	40
74119B	104.5	1.0	2.50	2.50	1.75	0.35	6	14
74120	96.3	2.0	8.64	4.32	5.19	0.60	15	67

Table B-24. Summary of Static Shear Tests (1980).

Material	γ_d	Test	Q		R		S		σ_3	$\sigma_1 - \sigma_3$	Remarks
	(lb/ft^3)		Ø (deg)	c (ton/ft^2)	Ø (deg)	c (ton/ft^2)	Ø (deg)	c (ton/ft^2)	(ton/ft^2)	(ton/ft^2)	
Zone II	118.6	Q	24	1.0	-	-	-	-	1.0	4.16	98% max density
	118.5	Q							2.0	5.19	@ opt m.c.
	119.2								5.0	9.44	
Zone II	112.5	Q	27.5	0.6	-	-	-	-	1.0	3.37	98% max density
	112.6								2.0	5.08	@ opt m.c.
	112.5								5.0	9.98	
Zone II	118.7	R	-	-	15	0.9	31	0.4	1.0	1.78	98% max density
	118.6								2.0	2.38	@ opt m.c.
	118.4								5.0	4.68	
Zone II	119.0	R	-	-	20	0.6	-	-	1.0	2.63	98% max density
	118.9								2.0	3.98	@ opt+2% m.c.
	118.9								5.0	6.57	
Zone II	112.6	R	-	-	15.5	0.9	-	-	1.0	3.05	98% max density
	112.4								2.0	3.83	@ opt m.c.
	112.2								5.0	5.86	
Zone II	112.7	R	-	-	19.5	0.7	-	-	1.0	2.88	98% max density
	112.8								2.0	3.85	@ opt+2% m.c.
	112.6								5.0	6.91	
Zone II	119.3	S	-	-	-	-	42	0.5	1.0	6.80	98% max density
	119.2								2.0	10.70	@ opt+2% m.c.
	118.5								5.0	22.37	
Zone II	118.7	S	-	-	-	-	30	0.5	1.0	2.92	98% max density
	118.7								2.0	4.93	@ opt m.c.
	119.0								5.0	11.09	
Zone II	112.5	S	-	-	-	-	33	-	1.0	2.76	98% max density
	112.4								2.0	4.95	@ opt m.c.
	112.2								5.0	11.84	
Zone II	112.6	S	-	-	-	-	34	-	1.0	3.03	98% max density
	112.4								2.0	5.36	@ opt+2% m.c.
	112.4								5.0	12.87	
Zone I	124.1	R	-	-	25	1.2	37.5	-	0.5	4.65	98% max density
	124.9								2.0	8.57	@ opt m.c.
	123.6								5.0	11.05	

DYNAMIC LABORATORY TESTS

10-11 Dynamic tests consisting of strain-controlled cyclic triaxial and resonant column tests were conducted on representative remolded samples of the Zone II borrow materials. A summary of the strain-controlled cyclic triaxial and resonant column test results are summarized on plate B-85 as variation of damping ratio and shear modulus with strain.

10-12 The Zone I borrow materials were tested to obtain dynamic properties and strengths. The strain-controlled cyclic triaxial and resonant column test results are summarized as variation of shear modulus and damping ratio with strain on plate B-85.

Borrow Area No. 2

10-13 Modification of the Corona Expressway and construction of the dike at the California Institution for Women will utilize materials from borrow area no. 2. Representative samples were obtained from borrow area no. 2 to determine embankment fill properties and were tested by the Division laboratory between September and December 1987. The samples were graded into coarse-grained material and fine-grained materials. The coarser are located in sections A and B of borrow area no. 2 (see pl. B-1). The finer grained materials are located in section C. The materials of section C are suitable for fill, but have lower strength values than those found in sections A and B because of the higher percentage of fines.

10-14 Representative coarser-grained materials were selectively blended. Compaction and consolidated-undrained triaxial shear tests with pore pressure measurements (R-tests) were conducted by the Division laboratory on samples remolded to 95 percent of maximum dry density (ASTM D 698) at 2 percent above optimum water content. The results of the static laboratory tests are summarized on plate B-87.

10-15 Representative fine-grained materials were selectively blended. Compaction, consolidated-undrained triaxial shear tests with pore pressure measurements (R-tests), and consolidation tests were conducted by the Division laboratory on samples remolded to 95 percent of maximum dry density (ASTM D 698) at 2 percent above optimum water content. The results of the static laboratory tests are shown on plate B-87.

Outlet Works

10-16 To obtain engineering properties of the existing bedrock foundation along the proposed outlet works alinement through the left abutment, undisturbed samples were subjected to R-type triaxial strength, unconfined compressive strength, and permeability testing. The tests were conducted by the Division laboratory between May and July 1983. A summary of the shear test results are presented on plate B-82.

10-17 Laboratory testing of overburden samples from the outlet works was performed in April 1987. The testing program was limited to mechanical analyses, and Atterberg limits and moisture content determinations. Laboratory test results are summarized on the soil logs of test holes presented on plate B-58.

Dike Foundations

10-18 As previously discussed, GDM phase investigations and design activities attempted to reduce the uncertainty about the site conditions and construction materials that would have significant impacts on the cost of the project. Final design for the dikes will include more extensive laboratory testing than could be accomplished within the time and cost constraints of the GDM. Additional laboratory investigations for each dike foundation will be performed during preparation of plans and specifications to verify conservative design assumptions.

10-19 The results of mechanical analyses, Atterberg limits, dry unit weight, and moisture content determinations of the dike foundations are presented on the soil logs on plates B-69 through B-77. The results of detailed laboratory tests consisting of organic content loss on ignition, compaction, maximum-minimum density, triaxial compression, unconfined compression, and consolidation tests on the foundation soils are summarized in table B-25.

Table B-25. Summary of Detailed Laboratory Tests for Dike Foundations.

	Test No.					
Dike	1	2	3	4	5	6
Auxiliary	x	x	x	x	x	
Aloca Aluminum Plant	x	x	x	x	x	
Corona Sewage Treatment	x	x	x	x	x	
California Institute for Women	x	x	x	x	x	x

1 = Compaction ASTM D 698.
2 = Maximum - Minimum.
3 = Triaxial Compression.
4 = Unconfined Compression.
5 = Consolidation.
6 = Organic Content Loss on Ignition.
x = Test Performed

XI. DESIGN VALUES

Dam Embankment and Foundation

11-01 The adopted design parameters are based upon the results of detailed laboratory tests on undisturbed and representative remolded samples. The design shear strengths were selected in general accordance with the guidelines outlined in EM 1110-2-1902, "Stability of Earth and Rockfill Dams," 1 April 1970. The selected design parameters are presented in table B-26.

Table B-26. Dam Embankment Design Values.

			Shear Strengths				
			Q		R		S
Material Type	γ_m (1)	γ_{sat} (1)	phi (2)	c (3)	phi (2)	c (3)	phi (2)
Random	135	139	24	600*	15	600*	35
Core	132	136	24	600*	15	400	32
Pervious	135	140	24	600*	32	1,600	36
Foundation							
Above El. 419	115	131	--	--	16	1,000	38
Below El. 419	115	131	--	--	--	--	38
Zone I	135	--	37	0	25	2,400	37
Zone II	129	--	24	600	16	800	31
Upstream Debris	106	106	--	--	0	200	--

* Values based on inclusion of tests on Zone II materials.
(1) lb/ft^3.
(2) degrees.
(3) lb/ft^2.

RANDOM

11-02 The design strength parameters for the existing random embankment materials are based upon triaxial tests conducted on composite samples of random materials obtained from the embankment and Zone II materials obtained from borrow area no. 1. The existing random embankment materials have engineering properties similar to the Zone II borrow materials. As indicated on plates B-46 and B-50, the samples of Zone II materials tested are finer than the average random materials. The composite samples from the embankment were remolded to 95 percent of maximum density (ASTM D 698) at 2 percent above optimum moisture content. The materials from the borrow area were remolded to 98 percent of maximum density at optimum and 2 percent above optimum moisture content. The results of R tests are summarized on plate B-84. A summary of p-q values and design R-shear strength are presented on plate B-86. The design R-shear strength was selected at Ø = 15 degrees and c = 600 lb/ft^2.

11-03 Q-triaxial shear tests were not conducted on the random materials. Q-design shear strengths were assumed to be the same as the Zone II materials. The assumption is conservative because Zone II materials are finer than the random materials and excess pore pressures are not anticipated in the random materials. Also, loading during construction of the raised embankment section would be minimal (see pl. B-84) and gradual, allowing consolidation to occur. The design Q-shear strength was selected at Ø = 24 degrees and c = 600 lb/ft^2.

11-04 S-design shear strength was based upon the effective strength determined from an R-triaxial tests conducted on composite random samples remolded to 95 percent of maximum density (ASTM D 698) at 2 percent above optimum moisture content and Zone II materials compacted to 98 percent of maximum density at 2 percent above optimum moisture content. The design S-shear strength was selected at Ø = 35 degrees.

CORE

11-05 The selection of design shear strengths for the core materials was determined from laboratory tests conducted on undisturbed and remolded composite samples. The results were compared with test results on Zone II materials from the borrow area no. 1. The composite samples from the embankment were remolded to 95 percent of maximum density (ASTM D 698) at 2 percent above optimum moisture content. The Zone II materials tested, based upon a statistical analysis of the core material gradations, are representative of the median gradation of the core materials. The test results are summarized on plate B-84. A summary of the p-q values and design R-shear strength is presented on plate B-86. The design R-shear strength was selected at Ø = 15 degrees and c = 400 lb/ft^2.

11-06 Q-type triaxial shear tests were not conducted on existing core materials. Q-strengths were assumed to be the same as for Zone II materials, based on gradational analysis. Excess pore pressures in the

existing core materials are not expected due to gradual embankment loading which would allow some consolidation to occur. Q-design shear strengths were assumed to be Ø = 24 degrees and c = 600 lb/ft^2.

11-07 The S-design shear strength was determined from direct shear tests and effective strengths from R-triaxial shear tests. The samples were compacted to 95 percent of maximum density (ASTM D 698) at 2 percent above optimum moisture content. Test results are summarized on plate B-84. A summary of p-q values and design S-shear strength is presented on plate B-86. The design S-shear strength was selected at Ø = 32 degrees.

PERVIOUS

11-08 The design shear strength parameters for the existing pervious materials was based upon R-triaxial and direct shear tests conducted on remolded composite samples compacted to 95 percent of maximum density (ASTM D 698) at 2 percent above optimum moisture content. The results of the R-triaxial test are summarized on plate B-84. A summary of p-q values along with the design R-shear strength are presented on plate B-86. The design R-shear strength was selected at Ø = 32 degrees and c = 1,600 lb/ft^2.

11-09 Q-type triaxial shear tests were not conducted on existing pervious materials. Q-design shear strengths were assumed to be the same as Zone II embankment materials. The assumption is conservative because the Zone II materials are significantly finer and excess pore pressures are not anticipated in the pervious materials due to their relative coarseness and gradual loading during construction which would allow consolidation to occur.

11-10 The selection of the design S-shear strength was based upon $\bar{R}$-triaxial shear tests (with pore pressure measurements) and direct shear tests conducted on remolded composite samples. The results of the shear tests are presented on plate B-84. A summary of the p-q values and the design S-shear tests are presented on plate B-86. The design S-shear strength was selected at Ø = 36 degrees.

FOUNDATION

11-11 The foundation materials in the streambed beneath the existing embankment, based upon soil logs, consists predominantly of medium dense to very dense sands, gravelly sands, and silty sands in that order. A typical section of the foundation at station 7+50 and profile of the foundation at the centerline of the embankment is shown on plate B-45. The section and profile, in general represent simplified and typical foundation conditions. To determine the shear strength of the cohesionless materials, S-triaxial shear tests were conducted on undisturbed and representative disturbed samples remolded to 38, 50, 60, and 80 percent relative densities. The results of the S-triaxial shear tests are presented on plate B-83. The summary of the p-q values and design S-shear strength is presented on plate B-86. The design S-shear strength was selected at Ø = 38 degrees.

11-12 The upper 35 feet (elevation 419 to 454 feet) of the embankment foundation contains lenses and pockets of gravelly, clayey, and silty sands, and silty and clayey sands (see pl. B-45). The gradations of these materials are similar to the pervious materials in the embankment (see pls. B-46 and B-51). The R-strength of the lenses and pockets of the finer materials were conservatively selected based upon the R-strength of the pervious materials. The R-strength of the upper 35 feet of the foundation was conservatively selected at Ø = 16 degrees and c = 1,000 lb/ft^2.

11-13 Sandy silt and sandy clay lenses and pockets occur intermittently between elevations 435 and 445 feet. Standard penetration tests indicate the materials to range from 4 (soft) to 22 (very stiff) blows/foot with the average of 13 blows/foot (stiff). The R-design shear strength of Ø = 16 degrees and c = 1,000 lb/ft^2 would be representative of the foundation materials containing discontinuous lenses and pockets of the sandy silts and sandy clays.

Borrow Area No. 1

ZONE I

11-14 The design shear strengths of the Zone I materials were based upon R-triaxial shear tests conducted on remolded samples from borrow area no. 1. The samples were remolded to 98 percent of maximum density (ASTM D 698) at optimum moisture content. More than 90 percent of the potential pervious material would be coarser than the sample tests (see pl. B-50). The results of the R-triaxial shear tests are summarized on plate B-84. A summary of p-q values along with the design R-shear strength are presented on plate B-86. The design R-shear strength was selected at Ø = 25 degrees and c = 2,400 lb/ft^2.

11-15 Q-type triaxial tests of the Zone I materials were not conducted because excess pore pressures are not expected. Excess pore pressures are not expected during construction due to the coarseness of the Zone I materials and the relative slow rate of material placement.

11-16 Design S-shear strengths were selected based upon R-triaxial shear tests. The results of the R-triaxial shear tests are summarized on plate B-84. The summary of the p-q values along with the design S-shear strength are shown on plate B-86. The design S-shear strength was selected at Ø = 37 degrees.

ZONE II

11-17 The selection of Zone II shear strength properties was based upon Q-, R-, and S-tests conducted on representative samples obtained from borrow area no. 1. The samples were remolded to 98 percent of maximum density (ASTM D 698) at optimum and 2 percent above optimum moisture content. The materials tested, based upon gradation, represent the mean gradation of the potential borrow area. The results of triaxial shear tests are summarized on plate B-84.

11-18 A summary of the R-triaxial p-q values and design R-shear strengths are presented on plate B-86. The design R-shear strength was selected at Ø = 16 degrees and c = 800 lb/ft^2.

11-19 A summary of the Q-triaxial p-q values and design Q-shear strength are presented on plate B-86. The design Q-shear strength was conservatively selected at Ø = 24 degrees and c = 600 lb/ft^2.

11-20 Design S-shear strengths were selected from the results of R- and S-triaxial shear tests. The results of the triaxial shear tests are summarized on plate B-84. The summary of p-q values and the design S-shear strength are plotted on plate B-86. The design S-shear strength was selected at Ø = 31 degrees.

Borrow Area No. 2

11-21 The design parameters for borrow area no. 2 are based upon the results of laboratory tests on representative samples remolded to 95 percent of maximum density. The shear strength values were obtained from results of consolidated-undrained triaxial shear tests on both the coarse-grained and the fine-grained materials. The samples were chosen to represent the range of materials that would be encountered in borrow area 2. The R- and S-strengths for the coarse-grained material were selected to be Ø = 15 degrees and c = 0.2 tons/ft^2, and Ø = 33 degrees and c = 0 tons/ft^2, respectively. The R- and S-shear strengths for the fine-grained material were selected to be Ø = 16 degrees and c = 0.4 tons/ft^2, and Ø = 30 degrees and c = 0 tons/ft^2, respectively. The results of the laboratory tests are summarized on plate B-87.

Outlet Works

OVERBURDEN

11-22 Design parameters adopted for the overburden materials at the Outlet Works are based on results of previous Prado Dam studies of laboratory testing on similar type materials.

11-23 The overburden materials along the outlet works alinement consist of older alluvium from the approach channel to the stilling basin, and Recent alluvium from the stilling basin to the downstream end of the outlet channel. The older alluvium is predominately gravelly silty sand/silty sand to sandy gravel in a moderately loose to medium dense state with no plastic fines. The design S-shear strength was selected at Ø = 35 degrees. The design field densities were selected to be 115 and 130 lb/ft^3 for moist and saturated unit weights, respectively. The Recent alluvium is typically silty sand and sand interbedded with sandy silt lenses, moderately loose to medium dense and nonplastic. The design S-shear strength was selected at Ø = 30 degrees. The design field densities were selected to be 110 and 125 lb/ft^3 for moist and saturated unit weights, respectively.

BEDROCK

11-24 The selection of the design S-shear strength was based on R-triaxial shear tests conducted on intact rock core samples. The rock cores are representative of the various bedrock groups in the left abutment area. The results of the triaxial shear tests were summarized in the form of a p-q plot presented on plate B-82. The design S-shear strength of $\emptyset = 34$ and $c = 0.5$ tons/ft^2 was found to be representative of the bedrock materials. The design dry field density of the bedrock was selected to be 120 lb/ft^3.

11-25 The bearing capacity for bedrock was based on unconfined compressive strength tests conducted on sandstone and siltstone core samples. Unconfined compressive strengths varied from 1.0 to 12.8 tons/ft^2. An allowable bearing capacity for the bedrock foundation was determined to be approximately 2.5 tons/ft^2 based on a factor of safety of 3. This value is considered to be conservative. Additional testing will be conducted during the Feature Design Memorandum phase.

PERMEABILITY

11-26 Dewatering of overburden and bedrock materials will be necessary to lower groundwater levels below the limits of excavation to assure stability of temporary slopes. Permeability coefficients for overburden materials were estimated to be from 0.3 to 30 ft/day for the older alluvium and from 0.03 to 3 ft/day for the Recent alluvium. The permeability coefficient for bedrock, based on laboratory results, was determined to be from 0.005 to 0.1 ft/day (see pl. B-82).

Dikes

EMBANKMENTS

11-27 Construction of the auxiliary dike, and the dikes at the Alcoa Aluminum Plant, Sewage Treatment Plant, and Corona National Housing Tract will utilize Type II materials from borrow area no. 1. Construction of the dike at the California Institution for Women will utilize materials from borrow area no. 2.

11-28 The adopted design parameters for each dike foundation are based upon the results of detailed laboratory tests on undisturbed and remolded samples and upon engineering judgement. These values are summarized in table B-27 and presented on plates B-88 through B-91.

Table B-27. Adopted Design Values for Dikes.

	Shear Strengths							
	R		S		Q			
	Ø$^{(1)}$	c$^{(2)}$	Ø	c	Ø	c	$\gamma_m^{(3)}$	$\gamma_{sat}^{(3)}$
AUXILIARY DIKE:								
Embankment	25	1.2	37	0.0	37	0.0	135	139
Foundation:								
Upper 15'	11	0.6	30	0.1	16	0.5	106	120
Below 15'	30	0.0	34	0.0	34	0.0	109	127
DIKE AT ALCOA ALUMINUM PLANT:								
Embankment	25	1.2	37	0.0	N/A		135	139
Foundation:								
Station 10+00 to 52+00								
SP-SM Layer	28	0.1	32	0.0	N/A		103	123
5' SC Layer	15	0.3	30	0.0	10	0.25	100	120
Station 52+00 to 60+50								
CL Above G.W.	18	0.3	---	---	16	0.3	119	N/A
CL Below G.W.	15	0.2	30	0.1	4	0.2	N/A	127
SP-SM Layer	32	0.1	35	0.0	N/A		103	124
DIKE AT CALIFORNIA INSTITUTION FOR WOMEN:								
Embankment	25	1.2	37	0.0	N/A		135	139
Foundation:								
Upper Clay	14	0.2	31	0.0	7	1.0	105	114
Lower Clay	31	0.4	38	0.0	0	0.4	127	130
Organic	13	0.2	15	0.0	9	0.1	85	87
DIKE AT CORONA SEWAGE TREATMENT PLANT:								
Embankment	25	1.2	37	0.0	N/A		135	139
Foundation:								
Upper 25'	14	0.1	31	0.0	17	0.30	119	126
Below 25'	33	0.8	35	0.0	N/A		115	120

Notes:
(1) degrees.
(2) tons/ft^2.
(3) lb/ft^3.

AUXILIARY DIKE

Upper 15 feet

11-29 The design Q-, R-, and S-shear strengths for the clayey sand/sandy clay (SC/CL) layer were derived from triaxial tests conducted on an undisturbed sandy clay (borderline sandy silt) cube sample. The design R- and S-shear strength values are ϕ = 11 degrees and c = 0.55 tons/ft^2 and ϕ = 30 degrees and c = 0.1 tons/ft^2, respectively. Based on laboratory triaxial tests, the Q-shear strength values are ϕ = 28 degrees and c = 0.7 tons/ft^2. The sample had 65 percent by weight passing the No. 200 sieve and a degree of saturation of 46 percent. The Q-shear strength is higher than expected due to possible sample disturbance during handling and transporting. The design Q-shear strength is ϕ = 16 degrees and c = 0.5 ton/ft^2.

11-30 The coefficient of consolidation (Cv) is based upon evaluation of the consolidation test results. The deformation versus time curves were evaluated by the square root of time method. A design Cv of 300 ft^2/yr was selected.

Below 15 feet

11-31 The silty gravelly sand (SM) was not tested for shear strength. The in-situ material is medium dense to dense based on SPT blow counts and was conservatively assumed to have design R-, S-, and Q-shear strength values of ϕ = 30, 34, and 34 degrees, respectively, and negligible cohesion.

DIKE AT ALCOA ALUMINUM PLANT

Station 10+00 to 52+00

11-32 The R- and S-shear strengths for the silty gravelly sand (SM) layer were obtained from the R-test on a sand (SP) remolded to 85 percent of maximum density. The tests indicated an R-shear strength of ϕ = 34 degrees and c = 0.25 tons/ft^2 and an S-shear strength of ϕ = 36 degrees and c = 0. The in-situ density of the SM is loose to medium based on SPT blow counts. The design R- and S-shear strengths were conservatively selected at ϕ = 28 and c = 0.1 tons/ft^2 and ϕ = 32 degrees and c = 0, respectively. The Q-shear strength is not applicable because the SM foundation soil will consolidate upon loading.

11-33 Residual drained strengths were assigned to the SM foundation for post earthquake stability analysis and are presented on plate B-118.

11-34 The 5-foot thick layer of clayey sand (SC) was not tested for shear strength. The design R-, S-, and Q-shear strength values were assumed to be ϕ = 15 degrees and c = 0.25 tons/ft^2, ϕ = 30 degrees and c = 0, and ϕ = 10 degrees and c = 0.25 tons/ft^2, respectively.

Station 52+00 to 60+50

11-35 The silty gravelly sand (SP-SM with 37 percent gravel sizes or larger) was not tested for shear strength. The design R- and S-shear strengths were assumed to have Ø = 32 and 35 degrees, and negligible cohesion, respectively. The Q-shear strength is not applicable because the SP-SM foundation soil should consolidate upon loading.

11-36 The design R- and S-shear strengths for the sandy clay (CL) layer were derived from triaxial tests ($\bar{R}$-tests) conducted on an undisturbed sandy clay sample (85 percent by weight passing the No. 200 sieve). The design R- and S-shear strength values for the clay below the groundwater was selected as Ø = 15 degrees and c = 0.2 tons/ft^2, and Ø = 30 degrees and c = 0.1 tons/ft^2, respectively. The shear strengths for these materials above the water table were slightly higher.

11-37 Unconsolidated-undrained triaxial shear tests (Q-tests) were conducted on samples obtained above and below the water table. The Q-shear strength above the water table was performed on an undisturbed CL cube sample (63 percent by weight passing the No. 200 sieve, "before shear" 73 percent degree of saturation). The design Q-shear strength above the water table was Ø = 16 degrees and c = 0.30 tons/ft^2. The Q-test strength below the water table was performed on an undisturbed CL sample (85 percent by weight passing the No. 200 sieve, "before shear" 100 percent degree of saturation). The Q-test strength below the water table was Ø = 0 degrees and c = 0.11 tons/ft^2. This sample was difficult to test and even though the in-situ consistency is soft to very soft based on SPT blow counts, the Q-shear strength obtained from the Q-test appears to be too low. Therefore, the design Q-shear strength was assumed to be Ø = 4 degrees and c = 0.2 ton/ft^2.

DIKE AT CALIFORNIA INSTITUTION FOR WOMEN

Upper Clay

11-38 The design R- and S-shear strengths for the clay (CH) layer are based upon $\bar{R}$-triaxial tests conducted on undisturbed samples. The design R-shear strength values are phi = 14 degrees and c = 0.18 tons/ft^2. The design S-shear strength values are phi = 31 degrees and c = 0. The design Q-shear strength values for the clay layer are based upon Q-triaxial tests conducted on undisturbed samples and are phi = 7 degrees and c = 1.0 tons/ft^2.

Lower Clay

11-39 The design R- and S-shear strengths for the sandy clay-sandy silt (CL-ML) foundation are based upon $\bar{R}$-triaxial shear tests conducted on undisturbed samples. The design R-shear strength values are phi = 31 degrees and c = 0.40 tons/ft^2. The design S-shear strength values phi = 38 degrees and c = 0. The CL-ML material was not tested for Q-shear strength. Based upon engineering judgement and past test results on similar materials the design Q-shear strength values are phi = 0 and c = 0.35 tons/ft^2.

Organic

11-40 The MH/OH foundation materials were not tested for shear strength. Based upon engineering judgement and past test results on similar materials, conservative values for design shear strengths were assumed. The design R-shear strength values are Ø = 13 degrees and c = 0.20 tons/ft^2. The design S-shear strength values are Ø = 15 degrees and c = 0 tons/ft^2 and the Q-design shear strength was chosen to be Ø = 9 degrees and c = 0.12 tons/ft^2.

DIKE AT CORONA SEWAGE TREATMENT PLANT

Upper 25 feet

11-41 The design R- and S-shear strengths for the clay (CL) are based upon R-triaxial tests conducted on undisturbed samples. The design R-shear strength values are Ø = 13.5 degrees and c = 0.1 tons/ft^2 and the design S-shear strength values are Ø = 31 degrees and c = 0. The design Q-shear strength values for the clay (CL) is based upon Q-triaxial shear tests on undisturbed samples and are Ø = 16.5 degrees and c = 0.3 tons/ft^2.

Below 25 feet

11-42 The silty gravelly sand foundation materials were not tested for shear strength. Instead, the design shear strength values were conservatively selected using both engineering judgement and past test results on similar materials. The design R-shear strength was assumed to be Ø = 33 degrees and c = 0.75 tons/ft^2, and the design S-shear strength was assumed to be Ø = 35 degrees and c = 0. The design Q-shear strength was not considered applicable due to the pervious nature of these materials.

DIKE AT CORONA EXPRESSWAY

Embankment

11-43 Borrow area no. 2 materials will be used to construct the dike at the Corona Expressway. Material design values used for the dike embankment design are shown in table B-28.

Foundation

11-44 The foundation for the dike consists of areas of compacted road fill and areas of bedrock. For design purposes, the design values were conservatively selected as shown in table B-28. The bedrock design values shown were established by comparison with values selected for the outlet works foundation.

Table B-28. Adopted Design Values for Dike at Corona Expressway.

Material	* Unit Weight *		* R-Strength *		* S-Strength *	
	γ_m (lb/ft^3)	γ_{sat} (lb/ft^3)	ϕ (deg)	c (tons/ft^2)	ϕ (deg)	c' (tons/ft^2)
Embankment (CL, Borrow No. 2)	124	128	16	0.4	30	0
Foundation (Bedrock)	130	---	---	---	34	0.5

XII. SEEPAGE ANALYSES

Prado Dam and the dikes are flood control structures that will retain water only during design flood conditions. The short duration of water impoundment behind the embankments will not be sufficient to induce steady state through seepage or underseepage conditions. Saturation fronts were conservatively determined for slope stability analyses only.

XIII. STATIC SLOPE STABILITY ANALYSES

Dam Embankment

METHOD OF ANALYSES

13-01 A circular arc computer program called STABS was used to determine the locations of critical circular surfaces for the modified dam embankment and foundation stability in accordance with EM 1110-2-1902. Use of the computer enabled more studies to be made and allowed for more variations in embankment sections and water surfaces. STABS, originally written by the University of California at Berkeley, was modified by the Kansas City District to handle double strength parameters and to calculate factors of safety for either the circular arc ordinary method of slices or Bishop's modified method. The calculated factors of safety using Bishop's modified method were higher than for the ordinary method of slices. The controlling circular arcs determined by the computer were checked manually using a graphical integration procedure. The calculated minimum factors of safety from the stability analyses using the ordinary method of slices are presented in tabular form on plate B-92 and the analyses are discussed in the following paragraphs.

End of Construction

13-02 Due to the gradual rate of material placement that would allow some consolidation to occur, the range of moisture contents to be specified, the location of the groundwater table below the embankment, and the relatively arid nature of the climate, it is improbable that excessive pore pressures would develop in the Zone II materials and existing dam embankment materials. Excess pore pressures would not develop in the foundation due to the relative coarse nature of the foundation materials which would dissipate excess construction pore pressures as rapidly as they would occur. Analyses were conducted using Q-strengths for the Zone II, core, random, and downstream pervious materials. The upstream pervious and foundation materials below elevation 419 feet, because of their relative dense and coarse nature, were assigned S-strengths. R-strengths were conservatively assigned to

the foundation materials above elevation 419 feet. The results of the stability analyses are presented on plate B-93. The minimum factor of safety for the upstream and downstream slopes is 1.4. The minimum allowable factor of safety is 1.4.

Sudden Drawdown

13-03 The upstream slope would be subjected to drawdown from the maximum water surface and from spillway crest to the controlled intake sill (elevation 465 feet). The flood routing curves indicate that the reservoir would draw down from the maximum water surface (elevation 589.9 feet) in a period of 13.25 days which corresponds to a drawdown rate of 9.4 ft/day. The reservoir design flood routing curves indicate that the reservoir would draw down from spillway crest (elevation 563 feet) in a period of 11 days which corresponds to a drawdown rate of 8.9 ft/day. The calculated minimum factors of safety are 1.0 for drawdown from maximum pool and 1.2 for drawdown from spillway crest. The minimum allowable factors of safety are 1.0 and 1.2, respectively. Combined R- and S-shear strengths were used below the phreatic surface and S-shear strengths were used above the phreatic surface. The results of the sudden drawdown stability analysis are conservative based upon the conservative assumption of the saturation front locations. The locations of the saturation fronts are presented on plate B-94. The saturation fronts are conservative because of the relatively short duration of pool storage during the design and PMF floods. Also, a transient FEM seepage analysis using the program SEEP2D indicated the saturation front in the embankment would draw down simultaneously with the flood pool.

Partial Pool

13-04 The upstream slope was analyzed for various water surface elevations with the phreatic surface extending horizontally through the random and core embankment materials (see pl. B-95). Combined (R+S)/2 and S-design shear strength envelopes as required in EM 1110-2-1902 were used in the analysis. The minimum factor of safety of 1.5 was determined for the critical pool elevation of 527.5 feet. The minimum allowable factor of safety is 1.5.

Steady Seepage

13-05 Prado Dam is a flood control structure. Retention of pools would occur only during flood operations. The duration of maximum flood pool storage, based on flood routing curves, would be less than 20 days. With the relatively short pool duration and the transient nature of the pool, a steady state seepage condition would not occur.

13-06 A debris pool at elevation 500 feet was used to analyze the downstream slope stability under the steady seepage condition. Design (R+S)/2 and S-shear strength envelopes were used in the slope stability analysis (see pl. B-92). The minimum factor of safety calculated was 1.5, the minimum allowable is 1.5. The failure surface of the minimum factor of safety is a near surface arc.

Spillway Training Dikes

13-07 The spillway training dikes were designed in general accordance with EM 1110-2-1913, "Design and Construction of Levees," dated 21 March 1978. The dikes would have 1V and 2H side slopes and be constructed of Zone I materials. Zone I materials are relatively free draining coarse-grained soils. Therefore, S-design shear strengths were used to determine the slope stability. The minimum factor of safety of 1.5 exceeds the minimum allowable factors of safety of 1.3 for end of construction; 1.0 for sudden drawdown, and 1.4 for intermediate reservoir level. Steady seepage was not analyzed due to the reservoir level being equal on both sides of the dike.

Dikes

13-08 Slope stability analyses were conducted for each dike in accordance with EM 1110-2-1902. The computer programs UTEXAS2 and I0013, both developed by the U.S. Army Engineers, were used. The circular search routine of UTEXAS2 using Bishop's Simplified Method was used to locate the critical failure arc in the analysis of each dike. Computer program I0013 used the Modified Swedish Method to calculate factors of safety for circular failure arcs. The controlling critical failure arcs were hand checked using Bishop's Modified Method. Seismic loading conditions were analyzed using a seismic coefficient of 0.15g as referenced in the EM.

13-09 A conservative steady seepage analysis was performed for each dike. As mentioned in Section XII: Seepage Analyses, steady seepage is unlikely to develop due to short durations of water impoundment.

AUXILIARY DIKE

13-10 The auxiliary dike was analyzed at its maximum height of 74.4 feet (elevation 594.4 feet). Groundwater was estimated to be at elevation 510 feet, 10 feet below the existing ground surface. The results of the analyses are summarized on plate B-117 and described below.

13-11 An end of construction analysis was made using Q-shear strengths for the embankment and foundation. The minimum factor of safety for the upstream and downstream slope is 1.8. The minimum allowable factor of safety is 1.3. The dike was also analyzed under seismic loading conditions, resulting in a minimum factor of safety for the upstream and downstream slopes of 1.3. The minimum allowable factor of safety under seismic loading is 1.0.

13-12 A sudden drawdown from maximum pool analysis was made using S-shear strengths above the drawdown surface and combined R- and S-shear strength envelopes below the drawdown surface. The maximum pool is at elevation 589.4 feet, 69.4 feet above the existing ground surface. The maximum pool would take 8 days to drawdown. The minimum factor of safety for the upstream slope is 1.0. The minimum allowable factor of safety is 1.0.

13-13 A partial pool with steady seepage analysis was made using S-shear strengths above the phreatic surface and (R+S)/2-shear strengths below the phreatic surface. The minimum factor of safety is 1.7 for the upstream slope with no pool (water at ground surface). The minimum allowable factor of safety is 1.5. The dike was also analyzed under seismic loading conditions, resulting in a minimum factor of safety for the upstream slope of 1.1 with maximum pool. The minimum allowable factor of safety under seismic loading is 1.0.

13-14 A steady seepage with maximum pool analysis was made on the downstream slope using S-shear strengths above the phreatic surface and (R+S)/2-shear strengths below the phreatic surface. The minimum factor of safety is 1.5. The minimum allowable factor of safety is 1.5. The dike was also analyzed under seismic loading conditions, resulting in a minimum factor of safety of 1.1. The minimum allowable factor of safety under seismic loading is 1.0.

DIKE AT ALCOA ALUMINUM PLANT

13-15 The dike at Alcoa Aluminum Plant was analyzed for slope stability at its maximum height of 30 feet (elevation 570 feet). The results of the analyses are summarized on plate B-118 and described below.

13-16 An end of construction analysis was conducted using Q-shear strengths for the embankment and R-shear strengths for the silty gravelly sand (SP-SM) foundation. Partially-consolidated shear strengths (between Q- and R-shear strengths) were used for the sandy clay (CL) foundation soils and the 5-foot thick SC layer. Groundwater was estimated at elevation 529.5 feet, 10.5 below the ground surface. During construction, the minimum factor of safety for the upstream and downstream slope was calculated as less than the minimum allowable factor of safety of 1.3. Therefore, to maintain embankment stability during construction, two design alternatives were evaluated to increase the minimum factor of safety: (1) use of high strength geotextile foundation reinforcement and (2) staged construction.

13-17 For alternative no. 1, high strength geotextile would be placed (warp direction transverse to the dike's longitudinal axis) on top of the prepared foundation prior to placement of embankment fill. The minimum calculated factor of safety is 1.5 and 1.0 for the without and with seismic loading conditions. Minimum allowable factor of safety under seismic loading is 1.0.

3-18 Staged construction of materials was also considered to insure embankment stability during construction. The dike would be placed at a controlled rate over an 8-month period until maximum height was attained. The minimum calculated factor of safety is 1.6 and 1.0 for the without and with seismic loading conditions.

13-19 A sudden drawdown from maximum pool analysis was made using S-shear strengths above the drawdown surface and a combined R- and S-shear strength envelope below the drawdown surface. The maximum pool

is at elevation 526 feet, 26 feet above the ground surface. The maximum pool would take just over 4 days to drawdown. The minimum factor of safety for the upstream slope is 1.1. The minimum allowable factor of safety is 1.0.

13-20 A partial pool with steady seepage analysis was made using S-shear strengths above the phreatic surface and (R+S)/2-shear strengths below the phreatic surface. The saturation front for the maximum pool was calculated while assuming the phreatic surfaces through the embankment for the partial pool elevations. The minimum factor of safety for the upstream slope with pool at elevation 553 feet is 1.9. The minimum allowable factor of safety is 1.5. The dike was also analyzed under seismic loading conditions, resulting in a minimum factor of safety for the upstream slope of 1.1 with maximum pool. The minimum allowable factor of safety under seismic loading is 1.0. As mentioned in paragraph 13-09, this analysis conservatively assumes steady seepage conditions are developed.

13-21 A steady seepage with maximum pool analysis was made on the downstream slope using S-shear strengths above the phreatic surface and (R+S)/2-shear strengths below the phreatic surface. The saturation front for the maximum pool was calculated. The minimum factor of safety is 1.6. The minimum allowable factor of safety is 1.5. The dike was also analyzed under seismic loading conditions, resulting in a minimum factor of safety under seismic loading of 1.0. The minimum allowable factor of safety is 1.0.

DIKE AT CALIFORNIA INSTITUTION FOR WOMEN

13-22 The dike at the California Institution for Women was analyzed at its maximum height of 25 feet (elevation 570.1). The results of the analyses are discussed below and are summarized on plate B-119.

13-23 The end of construction case was analyzed using S-shear strengths for the embankment and sandy clay-sandy silt (CL-ML) foundation materials. Q-shear strengths were used for the clay (CH) and silt/organic silt (MH/OH) foundation materials. The minimum factor of safety was calculated to be 1.9. The minimum allowable factor of safety is 1.3. The dike was also analyzed under seismic loading conditions resulting in a minimum factor of safety of 1.3. The minimum allowable factor of safety under seismic loading is 1.0.

13-24 The sudden drawdown from maximum pool case was analyzed using S-shear strengths above the drawdown surface and a combined R- and S-shear strength envelope below the drawdown surface. The assumed drawdown surface is shown on plate B-119. The minimum factor of safety for the upstream slope was calculated to be 1.1. The minimum allowable factor of safety is 1.0.

13-25 The partial pool with steady seepage case was analyzed using S-shear strengths above the phreatic surface and (R+S)/2-shear strengths below the phreatic surface. Phreatic surfaces were conservatively

assumed to be horizontal from the reservoir face to the centerline of the dike and then decreasing linearly down to the landside toe. The minimum factor of safety was calculated to be 1.5 for water surface elevation 545 feet. The minimum allowable factor of safety is 1.5. The dike was also analyzed under seismic loading conditions resulting in a minimum factor of safety of 1.0 for the upstream slope. The minimum allowable factor of safety under seismic loading is 1.0.

13-26 The steady seepage with maximum pool case was analyzed for the downstream slope using S-shear strengths above the phreatic surface and (R+S)/2-shear strengths below the phreatic surface. The saturation front for the maximum pool is shown on plate B-119. The minimum factor of safety calculated was 1.6. The minimum allowable factor of safety is 1.5. The dike was also analyzed under seismic loading conditions resulting in a minimum factor of safety of 1.1 for the downstream slope. The minimum allowable factor of safety under seismic loading is 1.0.

DIKE AT CORONA SEWAGE TREATMENT PLANT

13-27 The dike at the Corona Sewage Treatment Plant was analyzed at its maximum height of 55 feet (elevation 568.9). The results of the analyses are discussed below and are summarized on plate B-120.

13-28 The end of construction case was analyzed using S-shear strengths for the embankment and the silty sand (SM) layers. Q-shear strength was used for the clay (CL) foundation materials. The minimum factor of safety was calculated to be 2.0. The minimum allowable factor of safety is 1.4. The dike was also analyzed for seismic loading conditions resulting in a minimum factor of safety of 1.4. The minimum allowable factor of safety under seismic loading is 1.0.

13-29 The sudden drawdown from maximum pool case was analyzed using S-shear strengths above the drawdown surface and a combined R- and S-shear strength envelope below the drawdown surface. The assumed drawdown surface is shown on plate B-120. The minimum factor of safety for the upstream slope was calculated to be 1.0. The minimum allowable factor of safety is 1.0.

13-30 The partial pool with steady seepage case was analyzed using S-shear strengths above the phreatic surface and (R+S)/2-shear strengths below the phreatic surface. Phreatic surfaces were conservatively assumed to be horizontal from the reservoir face to the centerline of the dike and then decreasing linearly down to the landside toe. The minimum factor of safety was calculated to be 1.6 for a water surface elevation at 535 feet. The minimum allowable factor of safety is 1.5. The dike was also analyzed under seismic loading conditions resulting in a minimum factor of safety of 1.1 for the upstream slope. The minimum allowable factor of safety under seismic loading is 1.0.

13-31 The steady seepage with maximum pool case was analyzed for the downstream slope using S-shear strengths above the phreatic surface and (R+S)/2-shear strengths below the phreatic surface. The saturation

front for the maximum pool is shown on plate B-120. The minimum factor of safety calculated was 1.5. The minimum allowable factor of safety is 1.5. The dike was also analyzed under seismic loading conditions resulting in a minimum factor of safety of 1.0 for the downstream slope. The minimum allowable factor of safety under seismic loading is 1.0.

DIKE AT CORONA EXPRESSWAY

13-32 The dike embankment was analyzed using design strengths similar to those of the Zone II material in borrow area no. 1. The R-shear strength was used for the end of construction condition. The calculated factor of safety is 1.7. The minimum allowable factor of safety is 1.3. The relatively slow rate of construction would not allow excessive pore pressures to develop and would allow consolidation to occur. Results of the analysis are shown on plate B-121.

13-33 The embankment was analyzed assuming the water would drawdown immediately from elevation 586 to 520 feet. The PMF flood routing curves were used to determine a conservative saturation front. The calculated factor of safety for sudden drawdown from maximum pool elevation is 1.2. The minimum allowable factor of safety is 1.0. The results of the analysis are shown on plate B-121. The combined R- and S-shear strength envelope was used in the analysis.

13-34 The reservoir slope was analyzed for water surface elevations at 570 and 560 feet with the phreatic surface extended horizontally through the embankment. The (R+S)/2-design shear strength envelope was used for higher normal stresses and the S-shear strength was used for lower normal stresses. The calculated factors of safety are 1.5 and 1.4 for pool elevations at 570 and 560 feet, respectively. The minimum allowable factor of safety is 1.4. The results are shown on plate B-121.

13-35 The slope stability conditions for end of construction, partial pool at elevations 570 feet, and partial pool at elevation 560 feet were analyzed under earthquake loading. A seismic coefficient of 0.15g was used in the analysis. The calculated factor of safety for end of construction with earthquake loading is 1.2. The factors of safety for partial pool at elevations 570 and 560 feet are 1.2 and 1.3, respectively. The minimum allowable factor of safety is 1.0 for slope stability conditions under earthquake loading. The results are shown on plate B-121.

XIV. STABILITY UNDER EARTHQUAKE LOADING

Dam Embankment

14-01 Stability analyses were conducted to determine the effect of earthquake loading on the dam embankment and foundation. The analyses consisted of a simplified procedure using standard penetration test results and more detailed dynamic finite element studies. The analyses evaluate the effects of regional and local design earthquakes on the stability of the embankment and foundation at three pool levels: (1) pool empty with groundwater at ground surface, (2) operating pool at elevation 500 feet, and (3) spillway flood pool at elevation 563 feet. The condition of a flood pool at elevation 563 feet occurring simultaneously with the design earthquakes is considered highly improbable (combined probability of 10^{-6} per annum) due to the infrequent occurrence of the spillway crest flood and the relatively short pool duration. The analysis of the flood pool at elevation 563 feet was conducted only to obtain additional information. The pool empty and pool at elevation 500 feet would be the normal operating conditions.

14-02 The embankment is not susceptible to significant strength losses during earthquake shaking based upon the following:

a. The random and pervious materials were placed in 6-inch thick lifts and equipment compacted (see table B-5). Comparison of the average as-built random zone dry densities (124.5 lb/ft^3) to recent laboratory compaction tests (ASTM D 698) indicates that the random embankment materials have been compacted to an average density over 98 percent of maximum density.

b. Standard penetration tests indicate the random materials are very stiff with an average N value of 29 blows/ft.

c. Recent studies in China have indicated that clayey materials with the following characteristics are susceptible to strength loss during shaking:

Percent finer than 0.005 mm $<$ 15 percent
Liquid limit $<$ 35
Moisture Content $>$ 0.9 x liquid limit

The existing random embankment materials plot above the A-line and classify predominantly as clayey sands and sandy clays. The minus No. 4 material, based on the gradations, forms the matrix of random materials. The median percent finer than 0.005 mm of the matrix is 15 percent. Most of the materials have a liquid limit less than 35. The moisture contents of saturated random materials average less than 0.6 x liquid limit. For these reasons, the dam embankment was determined to be not susceptible to strength loss during earthquake shaking.

FINITE ELEMENT ANALYSES

14-03 The liquefaction potential of the foundation was analyzed in general accordance with the procedure outlined by Seed. The overall analysis procedure consists of static and dynamic finite element methods and determination of the stresses required to cause liquefaction from both standard penetration test blow counts and cyclic laboratory tests.

Static Analyses

14-04 A linear elastic, plane-strain gravity turn-on finite element program, DAMSP1, was used to determine pre-earthquake stresses in the embankment and foundation. The FEM mesh consists of 463 nodes and 395 elements and is shown on plate B-96. The linear elastic method was used in lieu of a nonlinear method based upon studies conducted by Lee and Idriss. The study concluded that a linear assumption of initial Young's Modulus, E_i, had little effect on initial stresses when compared to stresses determined by the nonlinear method.

14-05 Effective unit weight, Young's modulus, and Poisson's ratio were input parameters used by DAMSP1 to determine static stresses. Moist unit weights were used for materials above the phreatic surface and buoyant unit weights were used for materials below the phreatic surface. See table B-29 for material properties and plate B-97 for material distribution.

14-06 Young's modulus was determined from consolidated-drained triaxial shear test data using a third of the deviator stress at failure and the corresponding axial strain. The values for Young's modulus were selected based upon the density and relative density of in situ materials, SPT results, and approximate confining pressures. The selected values are presented in table B-29.

14-07 Poisson's ratio for the various materials were determined from consolidated-drained triaxial shear tests and from shear (V_s) and compression (V_p) wave velocities obtained from crosshole geophysical surveys. Poisson's ratios were calculated from the triaxial shear test data and crosshole shear (V_s) and compression (V_p) wave velocities using the following equations:

$$\mu = \frac{(\epsilon_v/\epsilon_z) - 1}{2}$$

where:

μ = Poisson's ratio
ϵ_v = Volumetric strain
ϵ_z = Axial strain

and

$$\mu = \frac{1}{2} \frac{V_p^2 - 2V_s}{V_p^2 - V_s^2}$$

where:

μ = Poisson's ratio
V_p = Compression wave velocity
V_s = Shear wave velocity

Poisson's ratio, determined from the consolidated-drained shear tests varied from 0.15 to 0.48. Poisson's ratio determined in the foundation from the P- and S-wave velocities varied from 0.38 to 0.43 between 0 and 20 feet, and from 0.48 to 0.49 between 20 and 50 feet. Values of 0.35 for unsaturated and 0.45 for saturated soils were selected as Poisson's ratios. The Poisson's ratios used for the various embankment material are presented in table B-29.

Table B-29. Static Finite Element Material Properties.

Material Number	Unit Weights γ_m (lb/ft^3)	γ_b (lb/ft^3)	Poisson's Ratio	Young's Modulus (kip/ft^2)
1 (P)	135.3	--	0.35	1,700
2 (R)	134.9	--	0.35	1,500
3 (C)	132.2	--	0.35	1,200
4 (P)	139.5	77.1	0.45	400
5 (R)	139.4	77.0	0.45	600
6 (C)	136.0	73.6	0.45	1,500
7 (F)	109.0	46.6	0.45	350
8 (F)	126.2	64.8	0.45	350
9 (F)	128.7	66.3	0.45	450
10 (P)	115.0	--	0.35	375
11 (F)	115.0	--	0.35	1,325
12 (F)	130.6	68.2	0.45	400
13 (F)	130.6	68.2	0.45	1,325
14 (F)	130.6	68.2	0.45	1,275
15 (F)	136.6	74.2	0.45	550
16 (F)	136.6	74.2	0.45	1,250
17 (F)	136.6	74.2	0.45	1,475
18 (F)	136.6	74.2	0.45	1,950
19 (F)	118.4	56.0	0.45	1,700
20 (P)	136.2	--	0.35	1,700
21 (C)	134.2	--	0.35	1,200
22 (I)	134.9	--	0.35	500
23 (II)	128.6	--	0.35	450

(F) = Foundation material.
(P) = Pervious material.
(R) = Random material.
(C) = Core material.
(I) = Zone I material.
(II) = Zone II material.

14-08 The stability of the embankment was evaluated for the following three pool conditions: (1) pool empty with groundwater at ground surface, elevation 475 feet, (2) operating pool at elevation 500 feet, and (3) flood pool at elevation 563 feet.

14-09 Seepage forces for the pool conditions were determined using a FEM program called SEEP2D. The pool at elevation 500 feet was analyzed as a steady state seepage condition. The flood pool at elevation 563 feet was analyzed as a transient seepage condition. The material

properties used in the seepage model and a typical seepage mesh are shown on plate B-98. The seepage forces for the pool empty conditions were assumed to be zero. The phreatic surface for the pool empty and the seepage forces for the pool at elevation 500 feet and flood pool at elevation 563 feet are shown on plates B-99, B-100, and B-101. The seepage forces were added to the DAMSP1 finite element model to determine the effective static stresses.

14-10 The results of the static finite element analyses for the three pool conditions were evaluated for discontinuities by contouring selected stresses using a computer program called CONTOUR. The effective vertical normal stress, ($\sigma x'$), the horizontal shear stress ($\tau xy'$) and the mean principal effective stress ($\sigma m'$) located at the center of each element was used as the input data for the contour plot. The contour plots for the selected stresses for the three pool conditions are presented on plates B-102, B-103, and B-104.

DYNAMIC ANALYSES

Design Earthquakes

14-11 Seismic parameters were recommended for regional and local fault zones capable of producing strong ground motions at the damsite. The recommended seismic parameters are listed in table B-2.

14-12 The San Andreas fault, based upon its great length, capability of generating 8+ magnitude earthquakes, and probability of producing an 8+ event within the next 125 years was selected as the regional fault capable of producing an earthquake which would generate strong shaking at the site. Other factors considered were the distance of the faults from the site, maximum credible earthquake, peak bedrock acceleration, and duration of strong shaking.

14-13 The regional design earthquake would be an 8+ magnitude event with a peak bedrock acceleration of 0.30g, and duration of strong shaking of 45 seconds. The CIT A-1, CIT A-2 and Seed-Idriss 8+ magnitude artificial accelerograph records were used in the dynamic analysis. The frequency content was evaluated by plotting the normalized acceleration response spectra of each record as presented on plate B-107. Also plotted are the mean and mean plus one standard deviation of the normalized acceleration spectra for 28 records of rock motions as determined by Seed, Ugas, and Lysmer. The mean plus one standard deviation is approximately the 84 percentile. The normalized spectral acceleration of the three records fall above the mean plus one standard deviation in the range of period of interest (1.0 to 1.5 seconds). Based upon the normalized response spectra in the period of interest, it is reasonable to assume that the results of a dynamic response analysis would not vary significantly with each record. It was decided to use the Seed-Idriss artificial 8+ accelerogram record scaled to 0.30g with a duration of strong shaking of 45 seconds. A plot of the accelerograph record used is shown on plate B-105.

14-14 The near source faults are faults located within 12 miles (20 km) of the site. These faults, the Chino, Whittier, and Elsinore faults, comprise the Whittier-Elsinore fault zone. The Whittier fault was selected as the fault that would generate the local design earthquake, based upon the moment magnitude, duration of strong shaking, and peak horizontal bedrock acceleration.

14-15 The local design earthquake would be a magnitude 6.5-7.0 event with a peak bedrock acceleration of 0.60g and a duration of strong shaking of 30 seconds. The Imperial Valley event of 15 October 1979 located at Bonds Corner and the artificial 7+ magnitude event developed by H.B. Seed for the Hayward fault were evaluated for the design accelerogram. The frequency content of the 140 and 230 degree components from the Bonds Corner and the artificial 7+ accelerogram were evaluated by plotting the normalized acceleration response spectra (see pl. B-107). Also plotted on plate B-107 are the mean and mean plus one standard deviation of the normalized bedrock acceleration spectra developed by Seed, Ugas, and Lysmer. Based on the normalized response spectra and the period of interest (1.0 to 1.5 seconds), the artificial Hayward record scaled to 0.60g with a duration of strong shaking of 30 seconds was used to represent the bedrock accelerations from a local event. A plot of the accelerogram used is shown on plate B-106.

Dynamic Material Properties

14-16 The dynamic material properties used in the dynamic FEM analysis were based upon laboratory tests on disturbed and undisturbed samples, field tests, and geophysical data. The laboratory results and geophysical data were used to determine the shear modulus (G), K_{2max}, total unit weights, and damping ratio. The dynamic material properties used in the dynamic analysis are presented on plate B-85 as variation on shear modulus and damping ratio. Material properties used are summarized on table B-30 and the distribution is presented on plate B-111.

14-17 Resonant column and strain-controlled cyclic triaxial test results on undisturbed samples were used to determine the shear modulus and damping ratios for the embankment materials. The parameters, K_{2max}, was determined for the existing random, pervious, and core materials from the laboratory test results using the following equation:

$$G = 1000\, K_2 \sqrt{\sigma_m'}$$

where:

G = Shear modulus at a particular strain level (kip/ft^2)
σ_m' = Effective mean confining pressure (lb/ft^2)
K_2 = Relational parameter between shear modulus and confining pressure.

Table B-30. Dynamic Finite Element Material Properties.

Material Number	Poisson's Ratio	Total Unit Weight (lb/ft^3)	K_{2max}	QUAD-4 Material Number
1	0.35	135.3	38	1
2	0.35	134.9	34	2
3	0.35	132.2	44	2
4	0.45	139.5	38	1
5	0.45	139.4	50	2
6	0.45	136.0	44	2
7	0.45	109.0	32	4
8	0.45	126.2	32	4
9	0.45	128.7	44	4
10	0.35	115.0	50	4
11	0.35	115.0	50	4
12	0.45	130.6	50	4
13	0.45	130.6	50	4
14	0.45	130.6	50	4
15	0.45	136.6	75	4
16	0.45	136.6	75	4
17	0.45	136.6	80	4
18	0.45	136.6	85	4
19	0.45	118.4	38	4
20	0.35	136.2	38	4
21	0.35	134.2	44	2
22	0.35	134.9	42	3
23	0.35	128.6	43	3

Note: QUAD-4 Material Number
1 = Pervious
2 = Random and Core
3 = Type I and II
4 = Foundation

14-18 Crosshole seismic shear wave velocities (V_s) were used to obtain shear modulus at small strains (G_{max}) in the foundation free field to a depth of 45 feet using the following equation:

$$G_{max} = \rho V_s^2$$

where:

G_{max} = Shear modulus at small strains
ρ = Mass density
V_s = Shear wave velocity

The parameter K_{2max} was determined using G_{max} and the equation above. The K_{2max} values determined from the shear wave velocities and from resonant column tests are shown on plate B-108. The results indicate the K_{2max} parameters determined from shear wave velocities correspond well with parameters obtained from resonant column tests to depths of 30 feet. Below 30 feet, the K_{2max} parameters from resonant column tests are significantly lower. This may be an indication of sample disturbance. Due to possible sample disturbance, the K_{2max} parameters determined from shear velocities were used to a depth of 45 feet.

14-19 Below a depth of 45 feet, K_{2max} parameters were extrapolated from apparent relative densities and material types. The average apparent relative density below a depth of 45 feet is 80 percent (see pl. B-108). Sands with a relative density of 80 percent have K_{2max} values of 60. The materials below 45 feet are predominantly dense gravelly sands. K_{2max} parameters in the free field were assumed to have a value of 75.

14-20 The average apparent relative densities of the foundation materials beneath the embankment are significantly higher than in the free field (see pl. B-108). To account for the higher apparent relative densities beneath the embankment, K_{2max} parameters were increased over the free field K_{2max} parameters. The K_{2max} parameters are listed in table B-30 and shown on plate B-111.

14-21 The core and random materials have similar normalized shear modulus and damping ratio curves (see pl. B-85) and were assigned the curves shown on plate B-85. It is reasonable to assume that assigning Zone I material normalized shear modulus and damping ratio curves to Zone II materials would have an insignificant effect on the dynamic response of the finite element model due to the relatively small quantity of Zone I material in comparison to the other material types in the model. Therefore, Zone I materials were assigned Zone II normalized shear modulus and damping ratio curves presented on plate B-85. The location of the material types are shown on plate B-111.

Dynamic Response

14-22 Empty pool, pool at elevation 500 feet, and flood pool at elevation 563 feet were the three pool conditions used in the dynamic response analyses. Dynamic response analyses were conducted to evaluate the effects of local and regional earthquakes on the dynamic stability of the foundation and embankment.

14-23 The dynamic response analyses was conducted using the computer program, QUAD-4. The program was developed by the University of California at Berkeley and is capable of handling both triangular and quadrilateral elements. A procedure is incorporated in the program to use strain-dependent damping and stiffness values. The dynamic response analysis was conducted to obtain a shear stress history within the elements of interest.

14-24 The irregular shear stress-time history as obtained from the dynamic response analysis requires conversion into a number of uniform cycles in order to allow a comparison to be made between laboratory cyclic shear strength and earthquake-induced dynamic shear stresses. The computer program, EQCYCLE, was used to convert the irregular shear stress-time history into an equivalent number of uniform cycles. The average strength curve in the program was used. For the dynamic response analysis, 20 and 10 equivalent uniform stress cycles were used for the 8+ and 6.5-7.0 magnitude events, respectively.

14-25 The Seed-Idriss artificial 8+ and Seed artificial 7+ accelerograms were used in the dynamic response analysis for the pool empty condition in order to determine which input motion was more severe.

Evaluation of Cyclic Strength

Laboratory Data

14-26 The cyclic shear strength for foundation and embankment materials were based upon the results of cyclic triaxial tests conducted on undisturbed samples. The cyclic shear strength is defined as the cyclic shear stress required to cause 5 percent strain in 10 (7+ magnitude) or 20 (8+ magnitude) equivalent cycles. The cyclic shear strength envelopes for foundation materials were based on the results of laboratory tests and are shown on plate B-109. The shear strength envelopes were developed from test results for K_c ratios of 1.0, 1.5, and 2.0 which corresponds to alpha (static shear stress ratio) values of 0.0, 0.19, and 0.34, respectively. Cyclic shear strength envelopes for intermediate alpha values were linearly interpolated.

14-27 Due to the variability of density and gradation of the foundation and embankment materials tested, a line of best fit was used to represent the laboratory test data points. The cyclic triaxial test results were plotted as stress ratio versus number of cycles required to cause 5 percent strain. A line of best fit was used to represent the stress ratio and number of cycles required to cause 5 percent strain for varying K_c ratios and confining pressures. The procedure described by K. Lee was used to determine the cyclic shear stress envelope for various K_c ratios from laboratory test data.

14-28 The undisturbed samples are representative of the finer fraction of the foundation materials. The results of the cyclic triaxial tests conducted on undisturbed foundation materials by the Division Laboratory in 1981 were compared to the results obtained from tests conducted by Converse Davis Dixon Associates in 1975. The comparison is shown on plate B-109 and indicates that for $K_c > 1.0$, the cyclic shear stress required to cause 5 percent strain in 20 cycles was significantly higher for the undisturbed samples tested in 1981. The 1981 test results indicate the following increase in cyclic shear strength: $K_c = 1.0$ strength increases 20 percent, for $K_c = 1.5$ strength increases 80 percent, and for $K_c = 2.0$ strength increases 80 percent. Test results of cyclic triaxial tests conducted in 1975 on remolded samples

are shown on plate B-109. The ratio of the cyclic strength of the undisturbed sample to the remolded sample is 1.43. A ratio near unity would indicate significant sample disturbance. Based on the comparison of tests results, it is reasonable to assume that the undisturbed samples tested in 1975 had been disturbed to some degree during handling.

14-29 The ratio between the laboratory shear stress required to cause 5 percent strain in 10 or 20 cycles to the induced equivalent uniform shear stress for 10 or 20 cycles for each element is the criteria used to evaluate the dynamic stability of the dam. A ratio of unity corresponds to a strain of 5 percent. A ratio of less than unity indicates 5 percent strain has been exceeded. A ratio of greater than unity corresponds to a strain less than 5 percent.

14-30 For the pool empty condition, a comparison was made using the artificial Seed 7+ and Seed-Idriss 8+ accelerograms (see pl. B-112). The results indicate the artificial Seed-Idriss 8+ accelerogram produces a slightly larger response in the FEM model than the artificial Seed 7+ accelerogram. It was therefore decided to use the Seed-Idriss 8+ accelerogram as the design bedrock motion.

14-31 The results of the comparison between the dynamic response analysis and laboratory cyclic strength for the normal operating conditions of pool empty (groundwater at the surface) and pool at elevation 500 feet and the condition of flood pool at elevation 563 feet and bedrock motion consisting of the Seed-Idriss 8+ accelerogram are presented on plate B-113. The results indicate the zones with strains of 5 percent or greater would occur in the upstream and downstream free field, and beneath the spoil fill area at the downstream toe. The foundation materials beneath the embankment have safety factors greater than unity.

Field Data

14-32 The liquefaction potential of the foundation materials in the free field and beneath the embankment was also evaluated by an empirical method described by Seed, Idriss, and Arango. The empirical method of analysis is based upon correlation studies of standard penetration test results and the performance of sandy foundations during past earthquakes. Standard penetration test data representing sands containing less than 12 percent gravels (plus No. 4 sieve) and 12 percent fines (minus No. 200 sieve) were used in the analysis. The SPT data were modified to an overburden pressure of 1 ton/ft^2.

14-33 The relationship of modified SPT results (N_1) versus the cyclic stress ratio (τ_{xy}'/σ_v') derived by Seed, Idriss, and Arango for various magnitude earthquakes causing a pore pressure ratio of 100 percent with a limited strain potential and $\sigma_v' = 1$ ton/ft^2 was used to evaluate the liquefaction potential of the foundation materials. The relationship is based upon correlation studies for level ground conditions and is shown on plate B-110. The relationships were

modified for application below the embankment, sloping ground conditions, by applying a correction factor C_α for varying values of the static shear stress ratio, alpha. The C_α correction factor was determined from laboratory cyclic shear test results (see pl. B-110). Values of alpha were obtained for the various foundation locations on the embankment cross section from the static FEM analysis.

14-34 The relationship of modified SPT results (N_1) versus the cyclic stress ratio (τ_{xy} / σ_v') for level ground conditions (alpha = 0.00) was modified by applying the C correction factors to the cyclic shear stress required to cause initial liquefaction to obtain the relationship between the modified penetration resistance, N_1, versus the cyclic stress ratio for various slope conditions (alpha $>$ 0.00). The curves to evaluate the liquefaction potential of sands during an 8+ magnitude earthquake for level and sloping ground conditions for various foundation locations under the embankment cross section are presented in plate B-110.

14-35 The liquefaction potential at the site was evaluated for an 8+ magnitude earthquake and 0.3g maximum bedrock acceleration. The cyclic stress ratios induced in the foundation were obtained from the dynamic analysis. The value of N_1 necessary to resist initial liquefaction of the foundation was determined for the induced cyclic stress ratios in the foundation from plate B-110.

14-36 The results on plate B-47 indicates the potential for liquefaction to be highest in the upstream free field above elevation 445 feet with an increase in resistance to liquefaction with depth. The results on plate B-47 indicate that liquefaction at the toe is questionable and the foundation beneath the dam is safe from liquefaction. The results of the empirical method are consistent with the results of the detailed finite element method.

POST-EARTHQUAKE ANALYSES

14-37 The post-earthquake stability of the embankment was evaluated by making the following assumptions:

a. Earthquake shaking has ceased.

b. Failure of the embankment is not caused by earthquake induced inertia forces.

c. The potential failure is the result of loss of strength in the saturated zones due to earthquake-induced pore pressure increase.

d. An undrained condition occurs at the cessation of shaking.

e. A drained condition occurs at some time after cessation of shaking when pore pressures start to dissipate.

The evaluation was conducted to determine the effect of reduced static strengths, due to earthquake induced pore pressures and dynamic loading, and static embankment stresses on the stability of the embankment and foundation. The stability analyses were conducted for the empty pool condition and pool at elevation 500 feet with steady state seepage. The flood pool at elevation 563 feet was not analyzed for post earthquake stability due to the low probability of the combined flood pool and design earthquake occurring simultaneously.

14-38 The static strengths were assigned using conservative assumptions as follows:

a. The entire foundation in the upstream free field was assumed to have liquefied and have no shear strength (see pl. B-114). Based on studies by Seed, Banerjee, and others, materials subjected to cyclic loading and high residual pore pressure would have some shear strength after cessation of shaking.

b. Drained and undrained static shear strengths were reduced 10 percent to account for strength loss due to cyclic loading. The embankment materials are well compacted and would have minimal reduction in strength after cessation of shaking.

14-39 For the condition after cessation of shaking where pore pressures have not started to dissipate, reduced undrained shear strengths were assigned to the saturated materials and reduced drained shear strengths were assigned to the unsaturated materials. After cessation of shaking and initiation of pore pressure dissipation, reduced drained shear strengths were used with excess pore pressure ratios assigned to the saturated materials.

14-40 The results of the post-earthquake stability analyses are presented on plate B-114. The results indicate that the critical condition occurs during the drained condition. Even with the conservative drained strength assumptions, the factor of safety against sliding would reach unity only when the excess pore pressure ratio is assumed to reach a level of 0.55.

14-41 With the assumptions used, should a slope failure occur for the debris pool condition, a catastrophic release of water would not occur due to the larger amount of available freeboard above the pool (94 feet). Slope failure would be associated with slope movement resulting in permanent slope displacements.

14-42 It is reasonable to assume that the post-earthquake factor of safety against sliding for the downstream slope would be higher than for the upstream slope based upon the lower groundwater elevation, the waste berm, and higher strength embankment materials.

14-43 Prado Dam may be affected by secondary surface fault offsets and ground cracking triggered by an event on the Whittier-Elsinore fault zone. Any cracking of the dam embankment would not affect the safety of the dam based upon the following:

a. The embankment core and Zone II fills consists of plastic materials that are highly resistant to cracking. Therefore, continuous transverse cracking through the embankment would be highly unlikely.

b. The embankment consists of materials moderately (random and pervious) to highly (core and Zone II) resistant to piping.

c. Under the normal operating conditions, pool at elevation 500 feet, 94 feet of freeboard is available should cracking and differential movements occur.

SUMMARY

14-44 The embankment materials under design earthquake loading would not undergo significant strength loss based upon the denseness and nature of the random materials. The dense nature of the pervious, random, and core materials is documented by the construction compaction procedure and resulting average as-built dry densities. The random materials also consist of clayey sands and sandy clays which are resistant to loss of strength during earthquake loading.

14-45 Based on the dynamic analyses, limited zones within the saturated foundation immediately upstream and downstream of the embankment toes indicate a potential for strains in excess of 5 percent and reduction in strengths under an 8+ magnitude earthquake. Excessive strains do not develop within the embankment or within the embankment foundation. Post-earthquake stability analyses indicate that even with the excessive strains and conservative strength reductions assigned within the zones identified by the dynamic finite element analyses, the embankment and foundation materials have sufficient strength to preclude instability when subjected to regional or local design earthquakes.

14-46 The dynamic stability analysis of Prado Dam for conditions of reservoir empty and reservoir at debris pool (elevation 500 feet) did not disclose any geotechnical features that would affect the safety of the dam during regional or local design earthquakes. Therefore, no remedial treatment of the existing embankment or foundation is required.

Dikes

14-47 The dikes were designed in accordance with the requirements of ER 1110-2-1806, "Eathquake Design and Analysis for Corps of Engineers Projects." Simplified procedures were used since the condition of a flood pool occurring simultaneously with the design earthquakes is

considered highly improbable (combined probablility of 10^{-6} per annum) due to the infrequent occurrence of design flood and the relatively short pool duration.

14-48 Failure of the dikes at the Corona Sewage Treatment Plant, Alcoa Aluminum Plant, Corona National Housing Tract, and California Institution for Women due to earthquake loading would not be catastrophic, but a costly annoyance to the homeowners and users. Failure of the auxiliary and the Corona Expessway dikes with high flood pool due to earthquake shaking would be catastrophic. These structures act as extensions of the dam and protect the downstream communities from floodflows.

14-49 The embankments and foundations were evaluated for instability and/or excessive deformations under earthquake loading by determining the in-situ and/or anticipated material properties of embankment and foundation materials. In addition, the auxiliary and Corona Expressway dikes were further evaluated by performing post-earthquake slope stability and simplified permanent deformation analyses.

14-50 The dikes will be compacted to a high relative compaction, an average of 98 percent of maximum density. Based upon their denseness and nature, these types of materials would not significantly lose strength under the design earthquake loading.

14-51 Both laboratory tests and field performance data have shown that structures constructed of materials similar to Zone II materials of borrow area no. 1 (clays and clayey sands) will not liquefy during strong shaking.

14-52 In addition, cohesionless soils liked those from borrow area no. 2 (sandy silts to silty sands) when compacted to a dense state as expected will also be resistant to loss of strength during earthquake loading.

14-53 For the dikes exclusive of the dike at the Alcoa Aluminum Plant, the foundation materials are alluvial deposits consisting of dense sandy clays and clayey sands. The materials are stratified with small lenses and pockets of sandy materials. Since dense clayey sands and sandy clays are resistant to loss of strength during earthquake loading, these foundation materials would not be susceptible to liquefaction or development of excessive strains.

14-54 The foundation materials in the upper 20 feet of the dike at the Alcoa Alunimum Plant are loose to medium dense silty sands. Literature indicates that these types of materials under saturated conditions have shown evidence of liquefaction under strong shaking. Therefore a post-earthquake static slope stability analysis was performed on the dike at the Alcoa Aluminum Plant, in addition to the auxiliary and Corona Expressway dikes.

14-55 Conservative reductions in strengths (R_u = 0.2) were used in the embankment materials and limited areas within the foundation materials were assumed to have liquefied with residual strengths (R_u = 0.3 to 0.55). Operating and maximum pool conditions were assumed. The minimum factors of safety for each embankment were 1.4, 1.1, and 1.2 for the auxiliary, Corona Expressway, and Alcoa Aluminum Plant dikes, respectively.

PERMANENT DEFORMATION

14-56 Estimated performanent deformations of the auxiliary, Corona Expressway, and Alcoa Aluminum Plant dikes were also determined using the simplified procedure developed by Makdisi and Seed. Strengths were conservatively reduced by approximately 15 percent for the embankment and foundation materials. Maximum base accelerations of 0.3 and 0.6g were assumed for the regional and local earthquake events, respectively. Displacements were less than 12 inches for each of the embankments and are graphically presented on plate B-121a.

XV. SETTLEMENTS

Dam Embankment and Foundation

15-01 Settlements were estimated based upon embankment stresses, obtained from DAMSP1, and results of consolidation tests conducted on Zone II and embankment materials.

15-02 Contours of vertical stresses within the embankment before and after raising are shown on plate B-115. Stress contours indicate the majority of settlement would occur beneath the raised fill section with essentially no settlements occurring in the upstream slope of the existing embankment.

15-03 Foundation settlements for sands were estimated from the constrained modulus. The constrained modulus was determined from compressional wave velocity and the following relationships:

$$D = V_p^2 \rho$$

where:

D = Constrained modulus
V_p = Compressional wave velocity
ρ = Mass density
$\epsilon = \dfrac{\sigma'}{D}$

where:

ϵ = Strain
σ' = Increased effective normal stress
$\Delta h = h\epsilon$

where:

Δh = Settlement
h = Thickness of layer

Based upon the gradations and thicknesses, it is reasonable to assume post construction settlement in the foundation due to sandy silt and clay and silty and clayey sand layers would be small. The sandy silt and clay and silty and clayey sand layers range in thickness from 1 to 15 feet and form a combined thickness ranging from 7 to 20 feet throughout the foundation. The median gradations of the materials have less than 25 percent by weight passing the No. 200 sieve. It is reasonable to assume that consolidation of the layers would be relatively rapid and would occur during construction due to the relatively short drainage paths and coarseness of the material.

15-04 Total estimated settlement of the embankment would be less than 22 inches (see pl. B-115). Primary settlement of the existing downstream pervious and foundation would be essentially completed during construction. Post construction settlements of the raised embankment crest would be less than 12 inches. Based upon the depth of alluvium and relatively uniform height of embankment, it is reasonable to assume that differential settlements of the crest would be uniform and resulting differential settlements small.

15-05 In the area of the outlet trench, zone II materials will be placed at wetter than optimum moisture contents and compacted to at least 100 percent maximum density (ASTM D 698). Moisture contents and densities will be carefully controlled to insure its flexibility and to permit settlement during construction. Consolidation curves on zone II materials compacted to 95 and 98 percent of maximum density at 2 percent above optimum moisture content were evaluated. These results indicate preconsolidation stresses of 4 to 5 tons/ft^2 that compare to approximately 60 to 75 feet of fill. Even though the maximum section would be approximately 100 feet deep, careful control of density and moisture content would minimize post-construction settlement and cracking. In addition, further consolidation tests will be performed during the preparation of plans and specifications to verify these assumptions on zone II materials remolded to high relative compaction.

Dikes

15-06 Foundation settlements at the dikes were estimated based upon results of consolidation tests in accordance with EM 1110-2-1904. Settlements of the coarse-grained embankments are expected to occur mostly during construction.

AUXILIARY DIKE

15-07 Settlement of the foundation is expected to be small and would take place during construction. Total estimated post-construction settlement of the embankment and foundation is expected to be less than 12 inches. The potential for differential settlement in the deeper gullies and washes will be minimized by overexcavating steep slopes to provide satisfactory surfaces for placement and compaction of fill.

DIKE AT ALCOA ALUMINUM PLANT

15-08 Settlement of the foundation is expected to take place during construction. Total estimated post-construction settlement of the embankment and foundation is expected to less than 24 inches.

DIKE AT CALIFORNIA INSTITUTION FOR WOMEN

15-09 Consolidation of the foundation material is expected to be small and would take place during construction. Total estimated post-construction settlement of the embankment and foundation is expected to be less than 12 inches. The potential for differential settlement in areas where relatively steep slopes exist will be minimized by over-excavating slopes to provide satisfactory surfaces for placement and compaction of fill.

DIKE AT CORONA SEWAGE TREATMENT PLANT

15-10 Consolidation of the foundation material would be small. Total estimated post-construction settlement of the embankment and foundation is expected to be less than 12 inches.

DIKE AT CORONA EXPRESSWAY

15-11 Settlement will occur during construction with negligible post-construction settlement. The foundation for the dike is mostly bedrock with variable depths of alluvial material and some compacted fill. Much of the overburden would be removed during construction and the remaining overburden would be proof-rolled before placement of fill material. These conditions would insure negligible foundation and differential settlement. On the reservoir side beneath the embankment toe, unsatisfactory materials will be excavated to bedrock or suitable foundation surfaces. The potential for differential settlement in areas where relatively steep slopes exist will be minimized by overexcavating to slopes no steeper than 1V on 4H to provide satisfactory surfaces for placement and compaction of fill.

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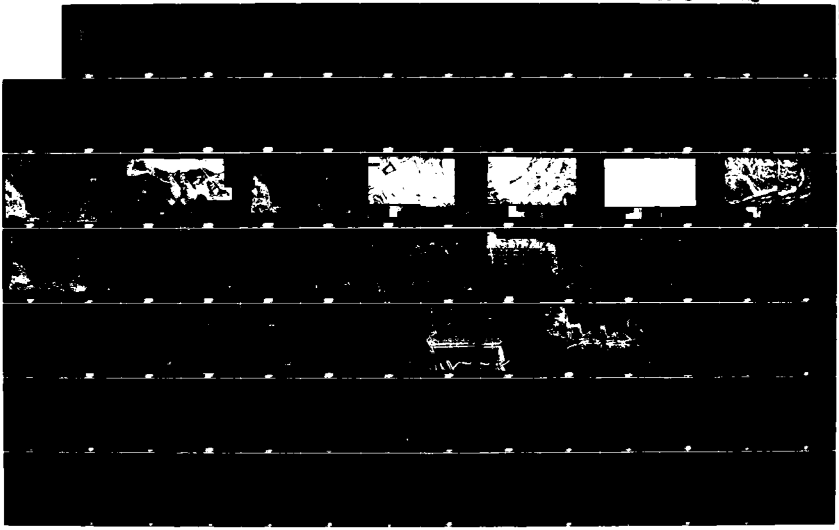

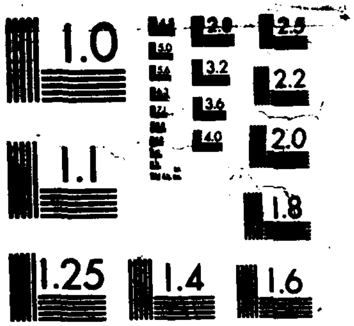

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XVI. SLOPE PROTECTION

Dam Embankment

UPSTREAM SLOPE

16-01 The upstream slope protection layer thickness and size were determined in general accordance with the requirements of the following references:

1. ETL 1110-2-221 titled "Wave Runup and Wind Setup on Reservoir Embankments," dated 29 November 1976.

2. ETL 1110-2-222 titled "Engineering and Design, Slope Protection Design for Embankments in Reservoir," dated 10 July 1978.

3. ETL 1110-2-305 titled "Determining Sheltered Water Wave Characteristics," dated 16 February 1984.

4. EM 1110-2-1101 titled "Design Criteria for Systems of Small Dams," dated 19 February 1968.

5. EM 1110-2-2300 titled "Earth and Rock Fill Dams, General Design and Construction Considerations," dated 10 May 1982.

6. 2nd Endorsement to Letter (10 August 1984) from DAEN-CWH-Y/D to Commander, South Pacific Division, Subject: Redbank and Rancher Creeks Project, Freeboard and Riprap Considerations," dated 21 November 1984.

In accordance with Appendix C of EM 1110-2-2300, the upstream slope of Prado Dam is classified into three zones according to frequency and duration of reservoir pool.

16-02 The class I zone extends from the toe of the dam to the 10-year water surface elevation plus the appropriate wave run-up. For Prado Dam, the pool elevation with a 10 percent chance of exceedence is

elevation 520.5 feet NGVD. The class II zone extends from the top of the class I zone to the uncontrolled spillway crest plus wave run-up. The spillway crest elevation is elevation 563 feet NGVD. The class III zone extends from the top of the class II zone to the top of the embankment, elevation 594.4 feet NGVD.

16-03 Class I and II zones cover elevations of the existing upstream slope protection. The existing slope protection consists of 12-inch thick stone paving over 6 inches of spalls. The existing riprap has been in service since 1941 with virtually no maintenance.

Design Wind

16-04 In accordance with EM 1110-2-2300, the wind-generated wave heights were developed from wind records in the vicinity of the project site (i.e., Corona Airport, Ontario Airport, Norton Air Force Base, and March Air Force Base). The design wind for the Class I zone is a 1 percent chance or 100-year wind. A fastest mile wind was estimated to be 91 mi/hr and the 100-year maximum one hour overland wind was selected as 45 mi/hr. This value was selected after analyzing the wind data and short duration of water impoundment at or above the class I zone at Prado Dam and vicinity. The design wind for the class II and III zones is a 50 percent chance or 2-year wind and was estimated to be 40 mi/hr.

Effective Fetch

16-05 As recommended by Reference No. 6 above, the effective fetch was computed using the method described in ETL 1110-2-305. The design fetch was taken as the arithmetic average of 9 fetches measured over a 24 degree sector centered around the nominal wind direction (northeast). The fetches were measured from the top of the embankments to the end of the maximum reservoir pool.

Design Wave, Significant Wave Height, and Wave Run-Up

16-06 As recommended by Reference No. 6 above, the significant wave height was determined using ETL 1110-2-305 and deepwater significant wave heights were determined using the Shore Protection Manual instead of ETL 1110-2-305.

16-07 The fastest mile, maximum 2-hour, 3-hour, 4-hour and 6-hour winds for the 100- and 2-year winds were obtained by multiplying maximum 1-hour overland winds by 1.25, 0.96, 0.93, 0.91 and 0.88, respectively. These overland wind speeds were coverted to overwater wind speeds by 1.1 (a neutral air/water temperature stability condition was assumed).

16-08 A design wind of 52 mi/hr from a northeast fetch (2.8 miles long) produces a class I zone wave run-up of 4.8 feet. The deepwater significant wave height was calculated to be 3.8-feet high, the wave length was 56 feet, the period was 3.3 seconds, and the wind setup was 0.3 feet.

16-09 A design wind of 44 mi/hr from a northeast fetch (3.7 miles long) produces a class II zone wave run-up of 4.3 feet. The deepwater significant wave height was 3.6-feet high, the wave length was 59 feet, the period was 3.4 seconds, and the wind setup was 0.1 feet.

16-10 A design wind of 43 mi/hr from a northeast fetch (5.0 miles long) produces a class III zone wave run-up of 4.3 feet. The deepwater significant wave height was 4.3-feet high, the wave length was 70 feet, the period was 3.7 seconds, wind setup was 0.1 feet. Shallow water waves were not considered.

16-11 The class I zone extends from the toe of the dam to the 10-year water surface elevation plus the appropriate wave run-up, 529.4 feet NGVD. The class II zone extends from the top of the class I zone to the uncontrolled spillway crest plus wave run-up, 571.0 feet NGVD. The class III zone extends from the top of the class II zone to the top of the embankment, elevation 594.4 feet NGVD.

Layer Thickness and Stone Size and Gradation

16-12 Appendix C of EM 1110-2-2300 was used to determine the layer thickness and stone size. Class I and II zones require stone protection of median weight (W_a) 160 pounds or approximately 12 inches in diameter. Since the existing stone paving (12-inches diameter) has been in service since 1941 with virtually no maintenance, it was determined that the existing slope protection is adequate to at least elevation 558 (8-feet below top of existing embankment crest). Class III zone, above elevation 558 to crest elevation 594.4 would be protected with a 24-inch thick layer of riprap (W_a = 220 lbs) over a 9-inch thick bedding layer over a 6-inch thick filter layer. Filter fabric (EOS = 70) may be substituted for filter materials. The riprap, bedding, and filter layers would have gradations as listed in tables B-31, B-32, and B-33.

Table B-31. 24-inch Riprap Gradation.

Weight of Pieces (lb)	Passing by Weight (percent)
1000	100
500	50-100
250	30-50
50	0-10

Table B-32. Bedding Gradation.

Sieve Size (in)	Finer by Weight (percent)
6	100
3	60-95
1-1/2	30-50
3/4	0-10

Table B-33. Filter Gradation.

Sieve Size (in)	Finer by Weight (percent)
3	100
1-1/2	80-100
3/4	60-80
3/8	20-45
No. 4	0-10

Filter requirements as indicated on plate B-122 were satisfied. The riprap, bedding, and filter materials would have a minimum specific gravity of 2.65 and the maximum abrasion loss after 1,000 revolutions of the Los Angeles Abrasion Test would be 50 percent.

DOWNSTREAM SLOPE

16-13 The existing downstream gravel slope protection can be salvaged, stockpiled, and placed on the new downstream slope. The gravel blanket will have a minimum thickness of 12 inches.

Dikes

16-14 The slope protection designs were determined in general accordance with the referenced EM's and ETL's.

UPSTREAM SLOPES

Auxiliary Dike

16-15 The design values used to design the slope protection for the dam embankment (described in the previous sections) were assumed to be very similar to those of the auxiliary dike. Under these assumptions, a design wind of 52 mi/hr from a northeast fetch (2.8 miles long) produces a class I zone wave run-up of 5.8 feet. The deepwater significant wave height was calculated to be 3.8-feet high, the wave length was 56 feet, the period was 3.3 seconds, the wind setup was 0.3 feet.

16-16 A design wind of 44 mi/hr from a northeast fetch (3.7 miles long) produces a class II zone wave run-up of 4.7 feet. The deepwater significant wave height was 3.6-feet high, the wave length was 59 feet, the period was 3.4 seconds, the wind setup was 0.1 feet.

16-17 A design wind of 43 mi/hr from northeast fetch (5.0 miles long) produces a class III zone wave run-up of 4.3 feet. The deepwater significant wave height was 4.3-feet high, the wave length was 70 feet, the period was 3.7 seconds, the wind setup was 0.1 feet. Shallow water waves were not considered.

16-18 The class I zone extends from the toe of the dike to the 10-year water surface elevation plus the appropriate wave run-up, 530.4 feet NGVD. The class II zone extends from the top of the class I zone to elevation 571.4 feet NGVD. The class III zone extends from the top of the class II zone to the top of the embankment, elevation 594.8 feet NGVD.

16-19 Most of the dike extends in class II and III zones, therefore the auxiliary dike would be protected with a 24-inch thick layer of riprap over a 9-inch thick bedding layer over a 6-inch thick filter layer. Filter fabric may be substituted for filter materials. The gradations for these materials are listed in tables B-31, B-32, and B-33.

Dike at California Institution for Women

16-20 The upstream slope protection would consist of an 18-inch thick layer of quarry waste (12-inch to No. 4 sieve) over filter fabric to protect the slope from surface erosion.

Dike at Alcoa Aluminum Plant

16-21 The upstream slope protection would consist of an 18-inch thick layer of quarry waste (12-inch to No. 4 sieve) over filter fabric to protect the slope from surface erosion.

Dike at Corona Sewage Treatment Plant

16-22 The upstream slope protection would consist of an 18-inch thick layer of quarry waste (12-inch to No. 4 sieve) over filter fabric to protect the slope from surface erosion.

Dike at Corona National Housing Tract

16-23 The upstream slope protection would consist of an 18-inch thick layer of quarry waste (12-inch to No. 4 sieve) over filter fabric to protect the slope from surface erosion.

Dike at Corona Expressway

16-24 The dike at the Corona Expressway would be designed similarly to the dam embankment and the auxiliary dike. The upstream slope protection would consist of a 24-inch thick layer of rip-rap over a 9-inch thick bedding layer over a 6-inch thick filter layer. The riprap, bedding, and filter gradations are listed in tables B-31, B-32, and B-34; and shown on plate B-122.

Table B-34. Filter No. 2 Gradation.

Sieve Size (in)	Finer by Weight (percent)
3/4	100
3/8	70-100
No. 4	45-75
No. 16	10-20
No. 30	0-10

DOWNSTREAM SLOPES

16-25 The downstream slope protection for each dike would be either a quarry waste blanket with a minimum thickness of 12 inches or landscaped native grasses.

XVII. CONSTRUCTION MATERIALS

Borrow Materials

17-01 Adequate quantities of suitable materials would be available from the potential borrow areas for construction of all project features within Prado Basin. Borrow area no. 1 material would be used for the modification of Prado Dam and the construction of the auxiliary dike, and the dikes at Alcoa Aluminum Plant, Corona Sewage Treatment Plant, and Corona National Housing Tract. Borrow area no. 2 would be used for construction of the dikes at California Institution for Women and Corona Expressway. The approximate quantities of materials required to construct the project features are summarized in table B-35. Borrow area no. 1 would yield approximately 7.0 million cubic yards of material to an average excavation depth of 15 feet. Borrow area no. 2 would yield approximately 11.0 million cubic yards to an average excavation depth of 15 feet.

Table B-35. Construction Materials.

Feature	Quantity
Main Dam:	
Fill, Zone I	142,000 c.y.
Fill, Zone II	803,000 c.y.
24" Riprap	35,000 ton
Bedding Material	12,000 ton
Filter	8,000 ton
Gravel	27,000 c.y.
Auxiliary Dike:	
Fill, Embankment	604,000 c.y.
24" Riprap	40,000 ton
Bedding Material	21,000 ton
Filter	10,000 ton
Concrete	2,000 c.y.
Spillway Dikes:	
Fill, Embankment	6,300 c.y.
24" Riprap	2,000 ton
Bedding Material	750 ton
Filter	500 ton
Dike at Corona Expressway:	
Fill, Embankment	812,000 c.y.
24" Riprap	39,000 ton
Bedding Material	14,000 ton
Filter	10,000 ton
Dike at Corona Sewage Treatment Plant:	
Fill, Embankment	544,000 c.y.
18" Quarry Waste	20,000 ton
Dike at Alcoa Aluminum Plant:	
Fill, Embankment	319,000 c.y.
18" Quarry Waste	16,000 ton
Dike at Corona National Housing Tract:	
Fill, Embankment	84,000 c.y.
18" Quarry Waste	6,000 ton
Concrete	630 c.y.
Dike at California Institution for Women:	
Fill, Embankment	167,000 c.y.
18" Quarry Waste	13,000 ton

ZONE I FILL

17-02 The Zone I materials are located beneath the Zone II materials in borrow area no. 1. Standard penetration data, test trenches, and borings indicate that the materials can be excavated with little difficulty. A balance factor of approximately 0.85 can be expected when compacting the material to an average density of 98 percent of maximum density obtained by ASTM D 698. Borrow area no. 1 should yield approximately 5.6 million bank cubic yards of Zone I materials which would make available 4.8 million cubic yards or about 33 times the required amount. Flooding and groundwater are not expected to cause significant impact during construction.

ZONE II FILL

17-03 The Zone II materials are located near the surface and vary in depth from 1.5 to 37 feet with an average depth of 10 feet. Standard penetration data, test trenches, and borings indicate that the materials can be excavated with little difficulty. A balance factor of 0.80 can be expected when compacting the material to an average density of 98 percent of maximum density determined by ASTM D 698. Borrow area no. 1 should yield approximately 1.8 million bank cubic yards of Zone II materials which would make available 1.4 million cubic yards or about 1.7 times the required amount. Flooding and groundwater are not expected to cause significant impact during construction.

RANDOM FILL

17-04 All of the dikes would be constructed as homogeneous embankment sections of random fill material. The material would be obtained from borrow area nos. 1 and 2. Borrow area no. 1 could be excavated to a maximum depth of 35 feet to obtain random fill materials. Borrow area no. 2 could be excavated to an overall average depth of 15 feet throughout the proposed boundary or it could be excavated to maximum depths of 40 feet in localized areas. Borrow area no. 2 has been divided into sections A, B, and C. The geotechnical properties of the materials in sections A and B are similar and preferred over materials located in section C. To facilitate the environmental mitigation of the area, it is proposed to excavate materials from section A for the first construction season, regrade and plant section A and excavate materials from section B during the second construction season, and if necessary, excavate materials from section C during the third construction season. The areas are delineated on plate B-1.

Slope Protection

17-05 Slope protection materials for the various project features would be available from nearby commercial rock quarries. Local quarries which have produced suitable stone within the past 5 years for Corps of Engineers' construction projects are listed in table B-36. All these sources are within 30 miles of Prado Dam. The Corona group quarries

(Corona-Pacific, Harlow and 3M) would be the closest sources of the project. Stone could also be obtained from the more distant Atkinson, Declezville, and Stringfellow operations in the Jurupa Mountains near Riverside. The Slover Mountain Quarry near Colton and the Fish Canyon Quarry near Azusa would also be potential sources of stone.

Table B-36. Rock Quarry Locations.

Quarry	Nearest City	Distance to Site (mi)
Atkinson	Riverside	16
Corona-Pacific	Corona	7
Declezville	South Fontana	16
Fish Canyon	Azusa	25
Harlow	Corona	9
Slover Mountain	Colton	22
Stringfellow	Riverside	16
3M	Corona	8

STONE QUALITY

17-06 Results of recent quality compliance tests conducted by SPD laboratory on stone samples from the quarries listed in table B-36 are summarized in table B-37. In addition, the most recent Corps of Engineers project associated with each quarrry source is shown. Although the quarries listed in table B-36 have provided suitable stone for Corps projects in the past, restrictions were placed on recent usage of stone from the Harlow Quarry near Corona. Stone from this source was accepted for use only as grouted stone in the Warm Creek-Santa Ana River Confluence project because of the breakdown which occurred during the June 1985 wetting and drying test. Material from Harlow Quarry has also demonstrated an unsatisfactory service record on the existing lower Santa Ana River levees between Weir Canyon Road and Katella Avenue because of its tendency to breakdown along incipient fractures. This fact might preclude or restrict the use of stone from Harlow Quarry on the Prado Dam project. Despite a high abrasion loss shown for the Declezville Quarry, stone from this quarry has previously been accepted for use on Corps projects based on proven satisfactory service records. Stone from Declezville was placed in the San Pedro Breakwater, completed in 1912, and has shown no appreciable deterioration since that time.

STONE ASSESSMENT

17-07 Approximate quantities of material required for stone protection for the various project features are presented in table B-35. More than one source may be required to supply the estimated 150,000-plus tons of riprap and bedding material required for the Prado Dam project.

Suitable stone may be available from additional quarries in the Riverside-Corona area or from other locations, but information on these potential sources is not included in table B-37 due to lack of either recent test data or service records on Corps projects. Although the majority of the sources have produced acceptable stone in the past, it cannot be assumed that they will continue to do so. Therefore, any stone source considered for use as slope protection will require further field inspection and evaluation, and may require additional quality compliance testing prior to stone placement.

Water

17-08 Water for embankment construction may be obtained from wells located in the basin or downstream of the dam. Water may also be obtained from the Santa Ana River when surface flows are present.

Concrete Materials

17-09 This section discusses the availability and suitability of concrete materials. Prior to the preparation of plans and specifications, a detailed concrete materials investigation will be prepared for the concrete structures at Prado Dam. The scope of the investigation will be in accordance with the requirements of EM 1110-2-2000, Standard Practice for Concrete, dated 5 September 1985.

AGGREGATE SOURCES

17-10 The following paragraphs summarize potential sources of concrete aggregates available for the project. The material sources listed are representative of those currently used by local producers. Detailed investigations, which evaluated the quality of the aggregates from these sources are in progress. Additional sources will be investigated and the complete analysis of the results will be presented in the Feature Design Memorandum addressing major items of concrete construction.

17-11 Blue Diamond Materials. This producer of concrete aggregate is located on an alluvial sand and gravel deposit along Santiago Creek in Irvine, CA. Blue Diamond has been at this location for 12 years and expects to be in production there for a minimum of 8 more. The plant produces 1-1/2-inch aggregate, 3/8-inch pea gravel, and washed concrete sand. Additionally the plant produces 3/4-, 1/2-, and 3/8-inch crushed rock as well as some boulders of up to three foot diameter. The plant has an annual output of approximately one million tons and is located 28 miles from Prado Dam.

Table B-37. Potential Stone Sources - Quality Compliance Test Results.

Rock Quarry	Rock Type	Specific Gravity Bulk (SSD)	Specific Gravity Appar-ent	Absorption (percent)	Sulfate Soundness (percent loss)	Abrasion (percent loss)	Date Tested(1)	Remarks(2)
Atkinson	Monzonite/ Monzodiorite	2.76	2.77	0.1	2.0	25.2	06/85	Sepulveda Basin
Corona-Pacific	Tonalite	2.67	2.68	0.3	0.5	14.1	04/88	San Pedro Breakwater.
Declezville	Granodiorite	2.77	2.79	0.3	2.3	46.5	11/83	Morro Bay North & South Breakwaters
Fish Canyon	Granite	2.74	2.76	0.4	1.5(3)	16.9	11/86	Redondo Beach (King Harbor) North Breakwater
Harlow	Andesite	2.66	2.66	0.2	1.6	14.3	06/85	Warm Creek-Santa Ana River Confluence
Slover Mtn.	Marble	2.72	2.73	0.2	1.0	38.0	11/83	Morro Bay North Breakwater
	Metasediment	2.90	2.92	0.3	1.2	27.2	11/83	
Stringfellow	Granite	2.66	2.67	0.2	0.4	18.3	06/85	San Pedro Breakwater
3M	Andesite	2.69	2.70	0.4	0.5	10.0	09/83	Dana Point Breakwater

NOTES:
1. Only the most recent test results are shown for each stone source.
2. Rock from Harlow Quarry was only suitable for use as grouted stone on the Warm Creek-Santa Ana River Confluence project due to 50 percent failure during the wetting and drying test. The Declezville Quarry has provided suitable rock for Corps of Engineers projects based on service records.
3. April 1982 test.

17-12 Foster Sand and Gravel. Foster Sand and Gravel is located along Temescal Wash near Corona, CA and consists of an alluvial sand deposit. Foster has been at this location since 1972 and expects to be in production there for a minimum of 25 more years. The plant produces chiefly sand for fine aggregate although about 15 percent of its output consists of 1-inch aggregate and 3/8-inch pea gravel. The plant has an annual output of approximately one million tons and is located in very close proximity to Prado Dam. Located in the immediate vicinity of Foster are several other producers of sand for use in concrete building including R.J. Noble, Chandler, Concrete Products Inc., and C. L. Pharris.

17-13 Owl Rock. The Owl Rock Plant in Rialto has been located along Lytle Creek since 1955 and expects to be in production there for a minimum of 80 more years. The site consists of an alluvial deposit and produces 1-1/2- and 1-inch aggregate, 3/8-inch pea gravel, and washed concrete sand. The plant has an annual output of almost two million tons and is located 30 miles from Prado Dam. While this source is not located in the immediate vicinity of the project area it is included since it supplies aggregate to many ready mix firms which are in the project area.

17-14 Transit Mixed Concrete. Transit Mixed Concrete mines a deposit along the San Gabriel River in Azusa, CA which is alluvial in nature. Transit Mixed has been at this location for over 40 years and expects to be in production there for a minimum of 15 more years. The plant produces 1-1/2- and 1-inch aggregate, 3/8-inch pea gravel, and washed concrete sand and has an annual output of over three million tons. It is located 25 miles from Prado Dam. Located in the immediate vicinity of Transit Mixed are several other aggregate producers including Blue Diamond Materials and Cal Mat.

CEMENTITIOUS MATERIALS

17-15 Cement Sources. There are a relatively wide variety of cement producers in and near the Los Angeles Basin which are capable of supplying cements certified by the Corps of Engineers ongoing cement certification program. Among these plants are the California Portland Cement Company plant Colton, the Kaiser plant at Victorville, and the Riverside Cement Company plant at Riverside. The following paragraphs summarize the types of cements which these plants produce. Table B-38 supplies prices of various cements from the sources specified, and table B-39 contains cost data on the shipping of cement.

17-16 The California Portland Cement Company plant at Colton, located approximately 25 miles north of Prado Dam, produces Type II and III cements conforming to the requirements of ASTM C-150.

17-17 The Kaiser Cement Company plant in the Lucerne Valley, located approximately 89 miles north of Prado Dam, produces Type II cement conforming to the requirements of ASTM C-150. This plant also produces a blended cement conforming to the requirements of ASTM C-595, Type IP.

17-18 The Riverside Cement Company plant at Riverside, California, located approximately 17 miles west of Prado Dam. This plant produces Type II cement conforming to the requirements of ASTM C-150.

17-19 The Southwest Cement Company plant at Victorville California, located approximately 66 miles north of Prado Dam, produces Type II and V cements conforming to the requirements of ASTM C-150.

Table B-38. Cement Prices In Dollars Per Ton.
(FOB Plant, December 1987)

	Cement Type			
Cement Plant and Location	IP	II	III	V
California Portland, Colton	--	73.00	78.00	--
Kaiser, Lucerne Valley	73.00	60.00	--	--
Southwestern, Victorville	--	64.00	--	80.30
Riverside Cement, Riverside	--	63.00	--	--

Table B-39. Cement Shipping Prices In Dollars Per Ton.
(December 1987)

Distance		Distance		Distance	
Miles	Cost	Miles	Cost	Miles	Cost
3-5	3.142	30-35	4.480	70-80	7.828
5-10	3.296	35-40	5.200	80-90	8.446
10-15	3.450	40-45	5.922	90-100	9.012
15-20	3.760	45-50	6.386	100-110	9.682
20-25	3.966	50-60	6.902	110-120	10.300
25-30	4.224	60-70	7.314	120-130	11.072

POZZOLAN SOURCES

17-20 ETL 1110-1-127, dated 17 August 1984 requires the Federal Government to allow the use of flyash in concrete construction except in those cases where it's use can be proven to be undesirable. The local practice of the ready-mix concrete industry is use flyashes as

pozzolanic admixtures in concrete. The reasons for this is the reduction of heat of hydration, reduction in cost due to the price of flyashes in comparison to the price of cement, increased workability at lower water contents, and the reduction in the alkali-aggregate reaction. The practice of local agencies is to specify Type F flyash generally conforming to the requirements of ASTM C-618. The Corps of Engineers has recently started a program to evaluate the quality and uniformity of flyashes and has set up a certification plan, for flyashes, similar to the one used for cements.

17-21 The closest local producer, the Western Ash Company, supplies flyash, conforming to the requirements of ASTM C-618, Type F, from a plant at Page, Arizona, approximately 555 miles northeast of Prado Dam.

17-22 Admixtures. A wide variety of admixtures are regularly used by ready-mix concrete suppliers in Southern California. These include all of the following: air entraining agents, accelerators, retarders, water reducers and high range water reducers. The relatively common methods anticipated for construction of the structures described above should not require any specialty admixtures other than those recommended in the section: Recommendations.

17-23 Water. Water of sufficient quantity and suitable quality for the production of concrete will be available from local municipal water systems.

17-24 Curing Compounds. A wide variety of curing compounds are available for use from the aggregate suppliers to the local ready-mix concrete industry. Curing compounds will be specified in accordance with project requirements and ASTM C-309.

17-25 Transit Mixed Concrete. Commercial ready mixed concrete plants are located within competitive hauling distances from Prado Dam. As of December, 1987 the approximate cost of a cubic yard of concrete in the project area is $60.00.

RECOMMENDATIONS

17-26 Aggregates. Aggregates potentially suitable for the production of concrete are produced at the sources previously discussed. These sources are capable of supplying sufficient amounts of aggregates to meet the needs of this project. With the exception of aggregates for use in mass concrete, coarse aggregate gradations would be as described in CALTRANS specifications, or would be size No. 467, No. 57, or No. 67 as described in ASTM C-33, as required by the design/engineer. All aggregate used shall conform to the requirements of ACI 350 and ASTM C-33 with the following limitations:

a. Soft particles: 2.0 percent.

b. Chert as a soft impurity (defined in Table 3 of ASTM C-33): 1.0 percent.

c. Total of soft particles and chert as a soft impurity: 2.0 percent.

d. Flat and elongated particles (long dimension more than 5 times short dimension): 15 percent.

e. Maximum aggregate size shall not exceed 1-1/2 inches, except where structural or other considerations require a difference.

17-27 Cements. The following cements and requirements will be specified.

a. Cement would be Type II, low alkali (0.6% maximum), conforming to the requirements of ASTM C-150.

b. Blended cements would conform to the requirements of ASTM C-595, Type IP.

c. For applications in which high early strengths would be desired due to construction scheduling, ASTM C-150, Type III cement would be acceptable.

17-28 Pozzolans. The only pozzolanic materials generally in use locally are Type F flyashes conforming to the requirements of ASTM C-618. There is a potential use of Type C flyash and its applicability will be discussed in applicable Feature Design Memorandums. Specifications will require flyashes conforming to the requirements of ASTM C-618.

17-29 Admixtures. The quality and use of admixtures will be specified for concrete construction in the following manner.

17-30 Accelerating Admixtures. Accelerating admixtures will conform to the requirements of ASTM C-494, Type C, except that no calcium chloride will be allowed in reinforced concrete. Calcium chloride is not permitted for reinforced concrete because of the deleterious effect it may create by accelerating the corrosion of the reinforcing steel in the concrete (ACI 201).

17-31 Retarding Admixtures. Retarding admixtures will conform to the requirements of ASTM C-494, Type B or D.

17-32 Water Reducing Admixtures. Water reducing admixtures will conform to the requirements of ASTM C-494, Type A or D.

17-33 Mix Proportioning. All materials used would be proportioned to produce a well-graded mixture of high density and maximum workability. Criteria for required minimum water-cement ratios, would be based upon EM 1110-2-2000, Standard Practice for Concrete.

XVIII. CONSTRUCTION PROCEDURES AND REQUIREMENTS

Dam Embankment

18-01 The modification of the dam embankment would be accomplished with conventional construction equipment. The specification requirements for gradation, moisture content, layer thickness and compactive effort for embankment materials are summarized below.

ZONE I AND II FILL

18-02 The Zone I and II materials would be excavated in such a manner to produce a uniformly blended material. Prewetting of the materials in borrow area no. 1 would be required. The moisture content would be specified to be between 3 percent above and 2 percent below optimum moisture content. The Zone I material would not have more than 20 percent of the material by weight passing the No. 200 sieve. Zone II materials would have at least 20 percent by weight passing the No. 200 sieve. Stones larger than 3/4 the lift thickness will be removed to the outside portion of the slope. The Zone I materials will be placed in 12-inch thick horizontal lifts and compacted with 8 passes of a 50-ton rubber-tired roller. The Zone II materials would be placed in 8-inch thick horizontal lifts and compacted with 8 passes of a tamping roller. The compactive effort will yield minimum in place densities of 95 percent maximum density determined by ASTM D 698. The average in place densities would be on the order of 98 percent of maximum density.

EXCAVATION

18-03 Excavation for the right abutment of the dam may be accomplished utilizing conventional methods. The overburden and the majority of the bedrock materials can be excavated with scrapers, loaders, and minimal dozer work. Ripping of harder or more conglomeratic bedrock layers may be required prior to excavation. Blasting should not be required.

SURFACE TREATMENT

18-04 The top 8 feet of the existing embankment would be excavated and stockpiled or used as Zone II material. The existing downstream slope protection would be removed and stockpiled for reuse on the newly constructed downstream slope. Prior to the placement of Zone II materials, the existing embankment surfaces will be scarified and moisture content adjusted to between 3 percent above and 2 percent below optimum moisture content.

18-05 Along the right abutment, in areas where bedrock has been exposed in the foundation excavation, all loose material will be removed using hand tools and air blasting prior to placement of embankment materials. Dental concrete may be required to fill bedrock depressions within the core zone not accessible to compaction equipment.

SLOPE PROTECTION

18-06 Slope protection will be placed with conventional construction equipment. The stone will be placed as the embankment fill is being placed. A gradall or large backhoe can be used to place the slope protection.

Outlet Works

EXCAVATION

18-07 Excavation for the various outlet works features may be accomplished utilizing conventional earthmoving equipment. The overburden materials can be excavated with scrapers, loaders, and minimal dozer work. Bedrock can probably be excavated using a combination of dozers, scrapers, loaders, and backhoes. Ripping of the harder or more conglomeratic bedrock may be required to facilitate excavation. Blasting should not be required, however. Temporary construction slopes will not be steeper than 1V on 1.5H in the overburden and 2V on 1H in unreinforced bedrock. Permanent design slopes will not be steeper than 1V on 2H in the overburden and 1.5V on 1H in the bedrock. A dewatering system will be required to achieve a drawdown of groundwater below the limits of excavation to assure stability of the temporary cut slopes. In the outlet conduit excavation, bedrock will be excavated vertically where practicable, and shotcrete will be applied to the vertical cut slopes to prevent air slaking and to provide stability. Additional information on excavation methods is presented in volume 2, appendix C.

Concrete Keywall

18-08 The "X-Y" trench concrete keywall, which extends through the left abutment to the spillway crest, will be encountered during excavation for the outlet conduits, see plate B-59. This will necessitate removal of that portion of the keywall within the limits of excavation. The keywall was designed to provide a cutoff between the bedrock and

embankment materials. Since excavation for the outlet works will extend below the keywall into the bedrock, a impervious backfill of Zone II materials will be provided in lieu of replacement of the keywall.

SURFACE TREATMENT

18-09 The outlet (RO) conduits, and the majority of the approach channel and stilling basin will be founded on bedrock. Where bedrock is exposed within the limits of excavation, all loose material will be removed using hand labor and air blasting to provide a clean foundation surface. Open or filled joints and fractures will be cleaned to a minimum depth of three times their width and sealed with grout slurry. Dental concrete placement will be required to provide a uniform foundation surface for structural concrete. Vertical bedrock slopes in the outlet conduit excavation will be stabilized with shotcrete. Additional information on surface treatment requirements is presented in volume 2, appendix C.

TEMPORARY SLOPES

18-10 Along the alinement of the outlet works, older alluvium overlies bedrock from the approach channel to the stilling basin, and Recent alluvium overlies bedrock from the stilling basin to the downstream and end of the outlet channel. Based on a selected phi = 35 degrees for the older alluvium and phi = 34 degrees and C = 1,000 lb/ft^2 for the bedrock, temporary excavated slopes along the alinement from the approach channel to the stilling basin should not be steeper than 1V on 1.5H for the overburden and 2V on 1H for unreinforced bedrock. These slope geometries are based on Wedge Method and infinite slope analyses. In areas of the outlet conduit excavation where bedrock can be excavated vertically, shotcrete application will be required to assure stability of the temporary cut slopes. Based on a selected phi = 30 degrees for the Recent alluvium, temporary excavated slopes for the remaining downstream portion of the outlet channel should not be steeper than 1V on 1.75H. Additional information on slope design is presented in volume 2, appendix C.

DEWATERING

18-11 Along much of the outlet works alinement, from the approach channel to the stilling basin, water levels from observation wells indicate that most of the bedrock within the limits of excavation is saturated. Both the older and Recent alluvial materials are also saturated within the limits of excavation along portions of the outlet works alinement. The older alluvium is saturated in those areas of the left abutment where the overburden/bedrock contact is below the piezometric surface, see plate B-60. The Recent alluvium downstream of the left abutment is saturated in the transition area between the stilling basin and the outlet channel. A higher yield can be expected from the Recent alluvium than from the older alluvium because of its relatively greater permeability coefficient. A dewatering system will be required to lower the groundwater table below the limits of excavation to assure stability of the temporary cut slopes. Additional information on dewatering is presented in volume 2, appendix C.

Dikes

RANDOM FILL

18-12 Random materials from borrow area nos. 1 and 2 shall be used in the embankments for each of the dikes. It shall be excavated in such a manner to produce a uniformly blended material. Prewetting of the materials in the borrow area may be required. The moisture content would be specified between 2 percent above and 2 percent below optimum moisture content. Stones larger than 3/4 of the lift thickness will be removed to the outside portion of the slope. The material will be placed in 12-inch horizontal lifts and compacted with 8 passes of a 50-ton rubber-tired roller. The compactive effort will yield minimum in place densities of 95 percent maximum density as determined by ASTM D 698. The average in place densities would be on the order of 98 percent of maximum density.

FOUNDATION TREATMENT

Auxiliary Dike

18-13 The foundation will be cleared, grubbed, stripped to 18 inches, and proof-rolled with 10 passes of a 50-ton rubber-tired roller. An exploration trench will be excavated to a maximum depth of 10 feet, with a base width of 15 feet and side slopes of 1V on 1H, as shown on plate B-15. In areas (gullies and washes) where slopes are steeper than 1V on 2H, the foundation will be overexcavated to slopes of approximately 1V on 4H to provide satisfactory surfaces for placement and compaction of fill.

Dike at Alcoa Aluminum Plant

18-14 The foundation will be cleared, grubbed, stripped to 12 inches, and proof-rolled with 10 passes of a 50-ton rubber-tired roller. The existing levees along the perimeter of the existing ponds will be removed where they underlie the embankment. An exploration trench shall be excavated to a maximum depth of 6 feet, with a base width of 15 feet and side slopes of 1V on 1H, as shown on plate B-15.

Dike at California Institution for Women

18-16 The foundation will be cleared and grubbed, stripped to 18 inches and proof-rolled with 10 passes of a 50-ton rubber-tired roller. An exploration trench will be excavated along the entire length of the dike to an average depth of 7 feet, as shown on plate B-16. The trench will be 15 feet wide and have side slopes of 1V on 1H. Flows from an existing 10-foot wide ditch will be diverted prior to construction to allow drainage of any localized surface water. Organic materials are considered undesirable as foundation materials and will be removed.

Dike at Corona Sewage Treatment Plant

18-17 The foundation will be cleared and grubbed, stripped to 18 inches and proof-rolled with 10 passes of a 50-ton rubber-tired roller. An exploration trench will be excavated along the entire length of the dike to an average depth of 18 feet as shown on plate B-16. The trench will be 15 feet wide and have side slopes of 1V on 1H. In areas where foundation surfaces are steeper than 1V on 2H, the foundation will be overexcavated to slopes of approximately 1V on 4H to provide satisfactory surfaces for placement and compaction of fill.

Dike at Corona Expressway

18-18 The dike at the Corona Expressway will be constructed of materials obtained from borrow area no. 2. Typical cross-sections are shown on plate B-17.

18-19 Excavation methods for the dike would be similar to those described for the dam embankment right abutment in paragraph 18-03.

18-20 The alluvial foundation will be cleared and grubbed, stripped to 12 inches and proof-rolled with 10 passes of a 50-ton rubber-tired roller. On the reservoir side beneath the embankment toe, unsatisfactory materials will be excavated to bedrock or suitable foundation surfaces. Where steep slopes exist, the materials will be overexcavated to slopes no steeper than 1V on 4H to provide satisfactory surfaces for placement and compaction of fill. In areas where bedrock has been exposed in the foundation excavation, only minimal surface treatment will be required to provide a clean bedrock surface prior to the placement of embankment materials.

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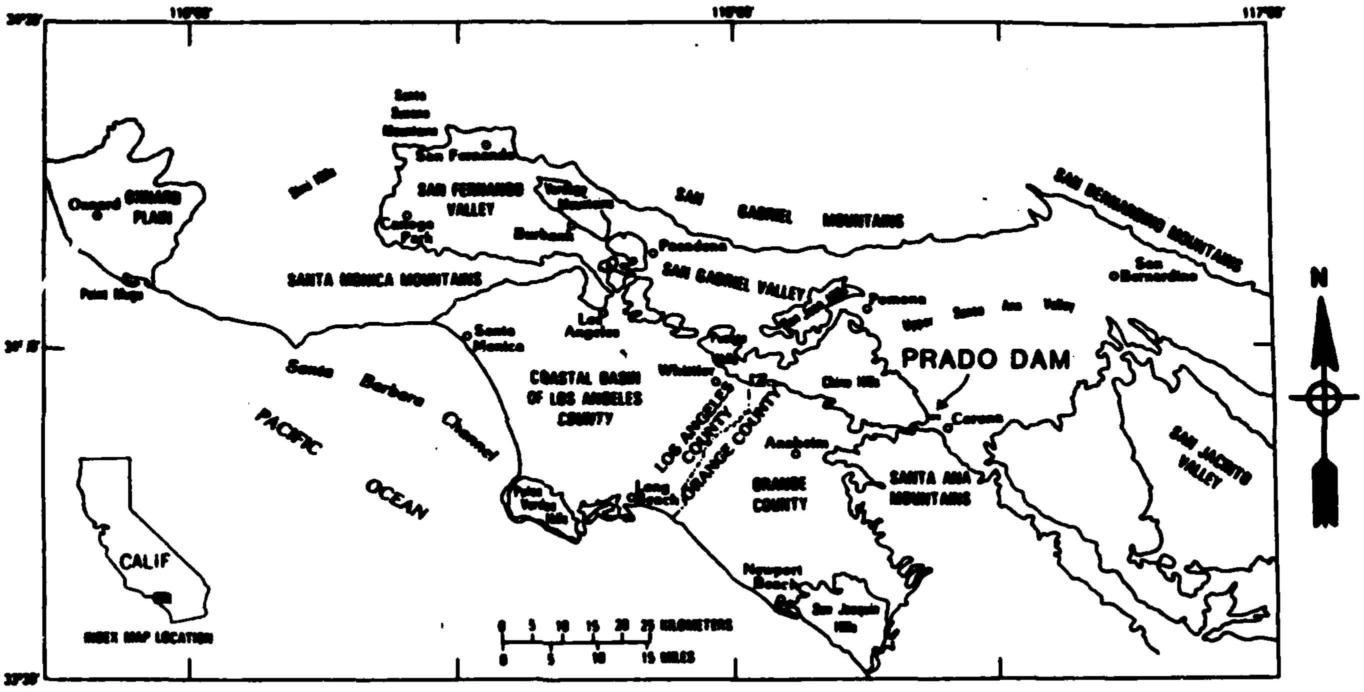
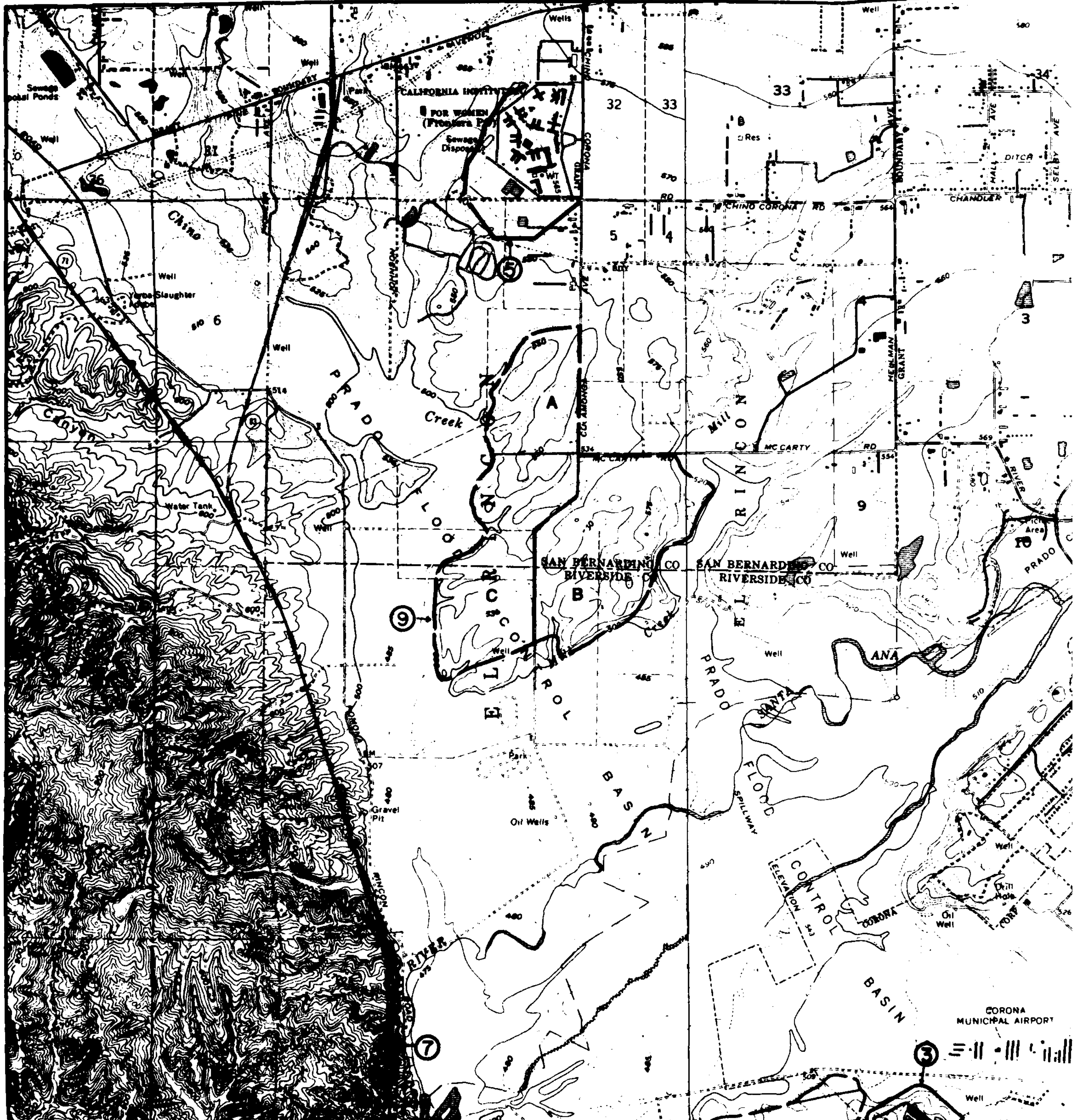
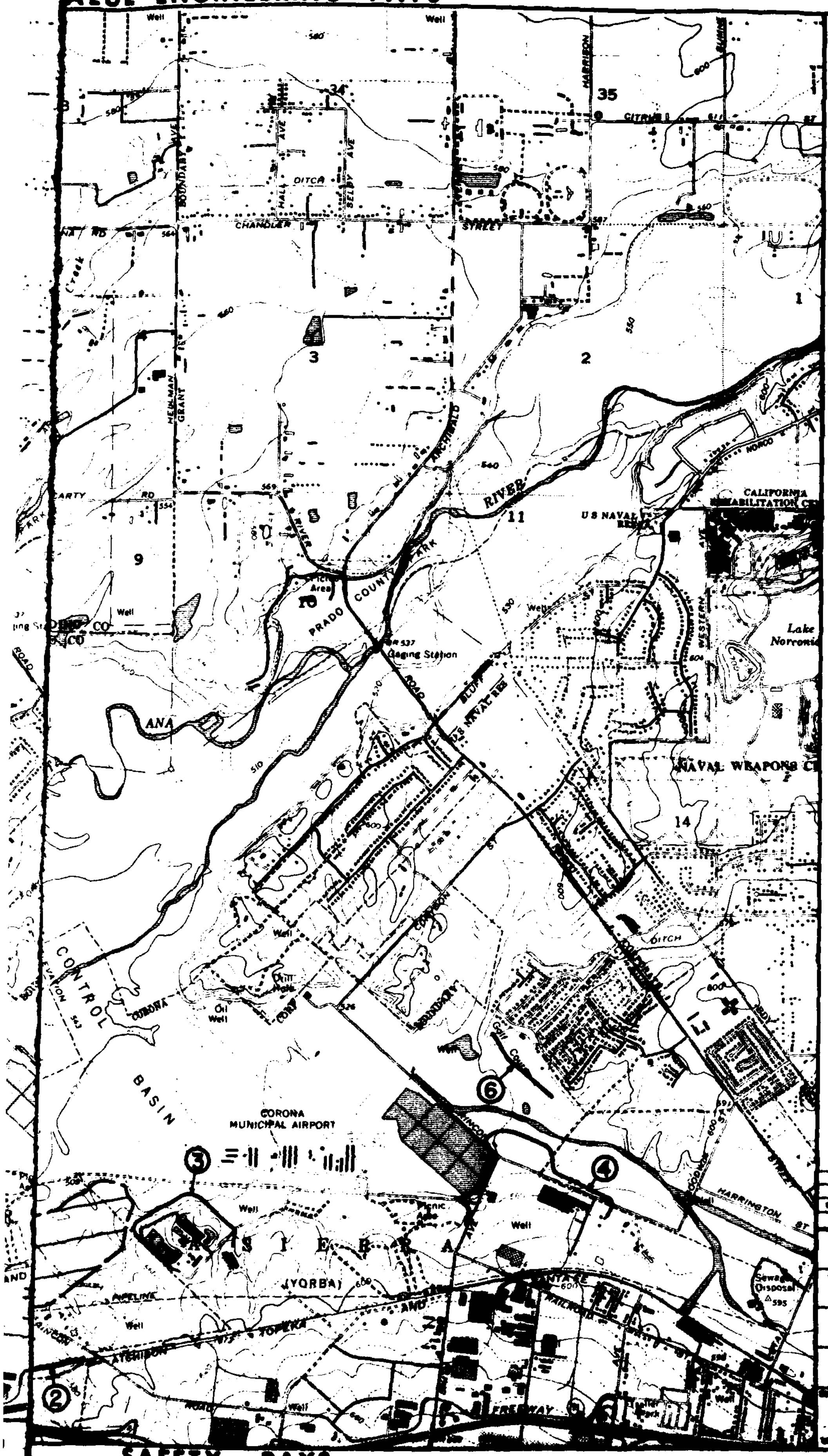


INDEX MAP OF THE LOS ANGELES REGION SHOWING MAJOR ALLUVIAL BASINS (FROM TINSLEY AND FUMAL, 1985)

FIGURE B-1


Sewage Disposal Ponds
Well
CALIFORNIA INSTITUTION FOR WOMEN (Frontera Park)
Sewage Disposal
BOUNDARY
32
33
33
34
Res
CHINO CORONA RD
CHANDLER
DITCH
HALL AVE
SELBY AVE
BOUNDARY AVE
5
4
Chino
Creek
Yorba-Slaughter Adobe
6
3
PRADO
Creek
A
MILL
Creek
RINCON
MC CARTY RD
Canyon
Water Tank
Well
FLOOD
9
SAN BERNARDINO CO
RIVERSIDE CO
SAN BERNARDINO CO
RIVERSIDE CO
C
B
⑨
EL RINCON CONTROL
PRADO
SANTA
ANA
Picnic Area
PRADO
Park
Gravel Pit
Oil Wells
BASIN
FLOOD
SPILLWAY
ELEVATION
CONTROL
CORONA
Oil Well
Drill Hole
BASIN
RIVER
⑦
CORONA MUNICIPAL AIRPORT
③
⑧
PRADO DAM
①
(YORBA)
POMONA RINCON
PIPELINE
TOPEKA
ATCHISON
SANTA FE
②
Gaging Station
SANTA
Wardlow
Wash
Lake
ROAD
⑤
⑥
480
500
560

VALUE ENGINEERING PAYS



SAFETY PAYS

PRADO BASIN

① PRADO DAM
② AUXILIARY DIKE
③ DIKE AT CORONA SEWAGE TREATMENT PLANT
④ DIKE AT ALCOA ALUMINUM PLANT
⑤ DIKE AT CALIFORNIA INSTITUTION FOR WOMEN
⑥ DIKE AT CORONA NATIONAL HOUSING TRACT
⑦ DIKE AT CORONA EXPRESSWAY
⑧ BORROW AREA NO.1
⑨ BORROW AREA NO.2

NOTES:

1. SEQUENCE OF BORROW USE IS A.B.C

PLAN

SCALE 1000 0 1000 2000 3000 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

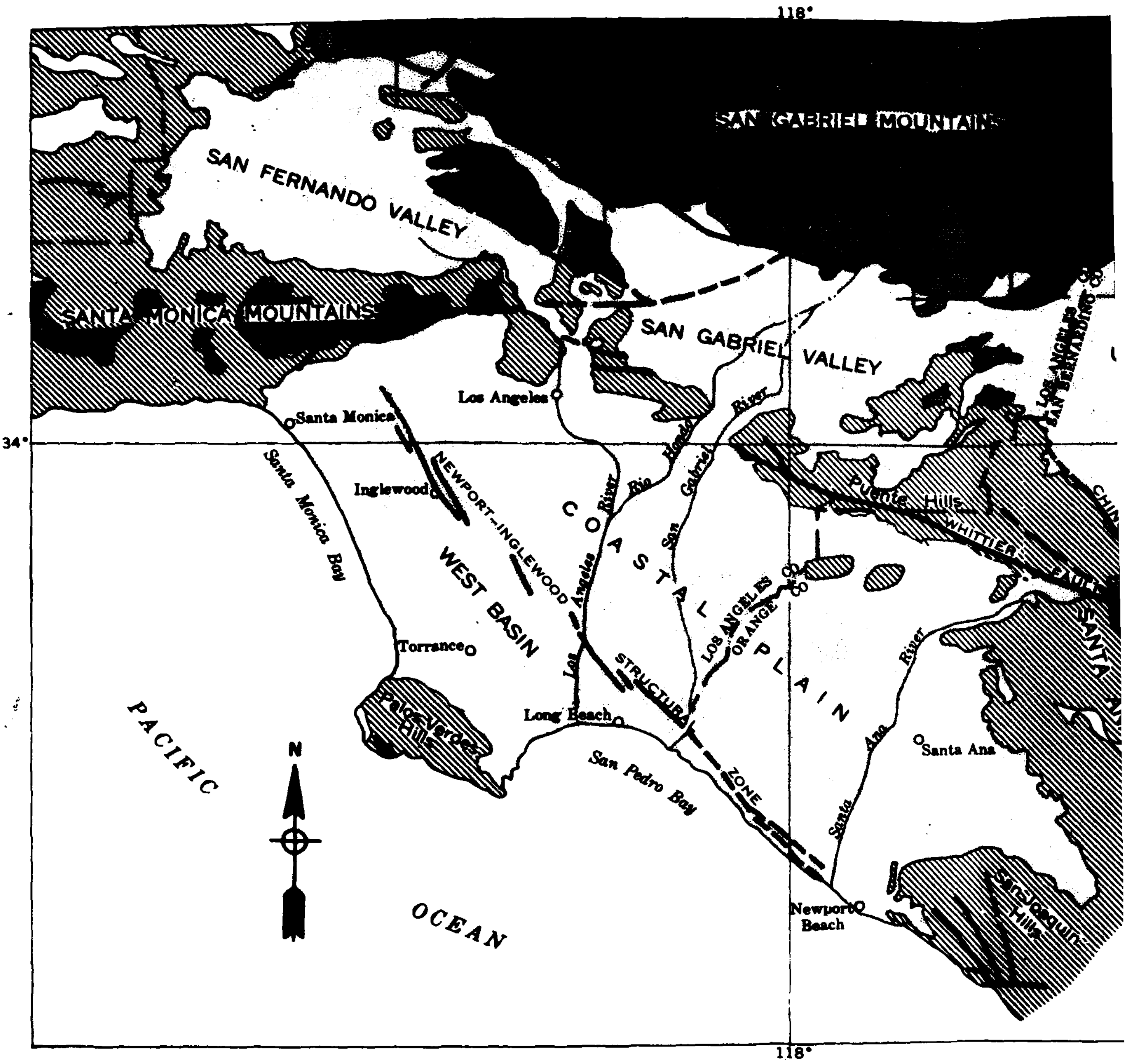
PRADO DAM
LOCATION OF PROJECT ELEMENTS

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-1

1

7



Base map and fault pattern largely after Geologic Map of California (Jenkins, 1938)

EXPLANATION

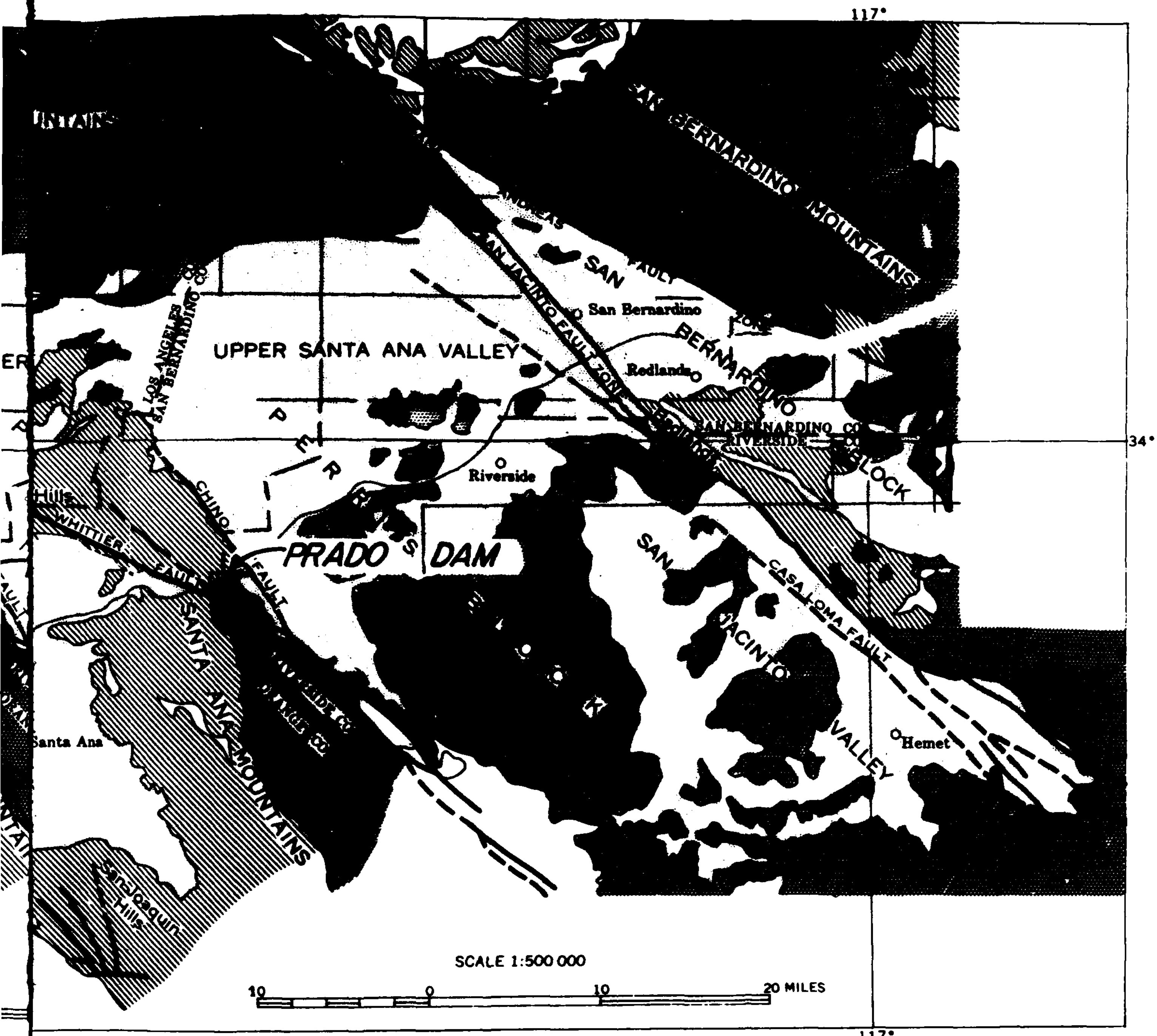
☐ Alluvium and associated deposits of Recent or Pleistocene age

■ Crystalline and metamorphic rocks of Jurassic or greater age; some volcanic rocks of Tertiary age

▨ Sedimentary r largely of part of Cr age

1

CORPS OF ENGINEERS



XPLANATION

▨

ks
f m ne
ary
ous

▨ Sedimentary rocks of marine origin; largely of Tertiary age but in part of Cretaceous or Triassic age

Contact

Fault
Dashed where inferred; dotted where concealed

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
REGIONAL GEOLOGY

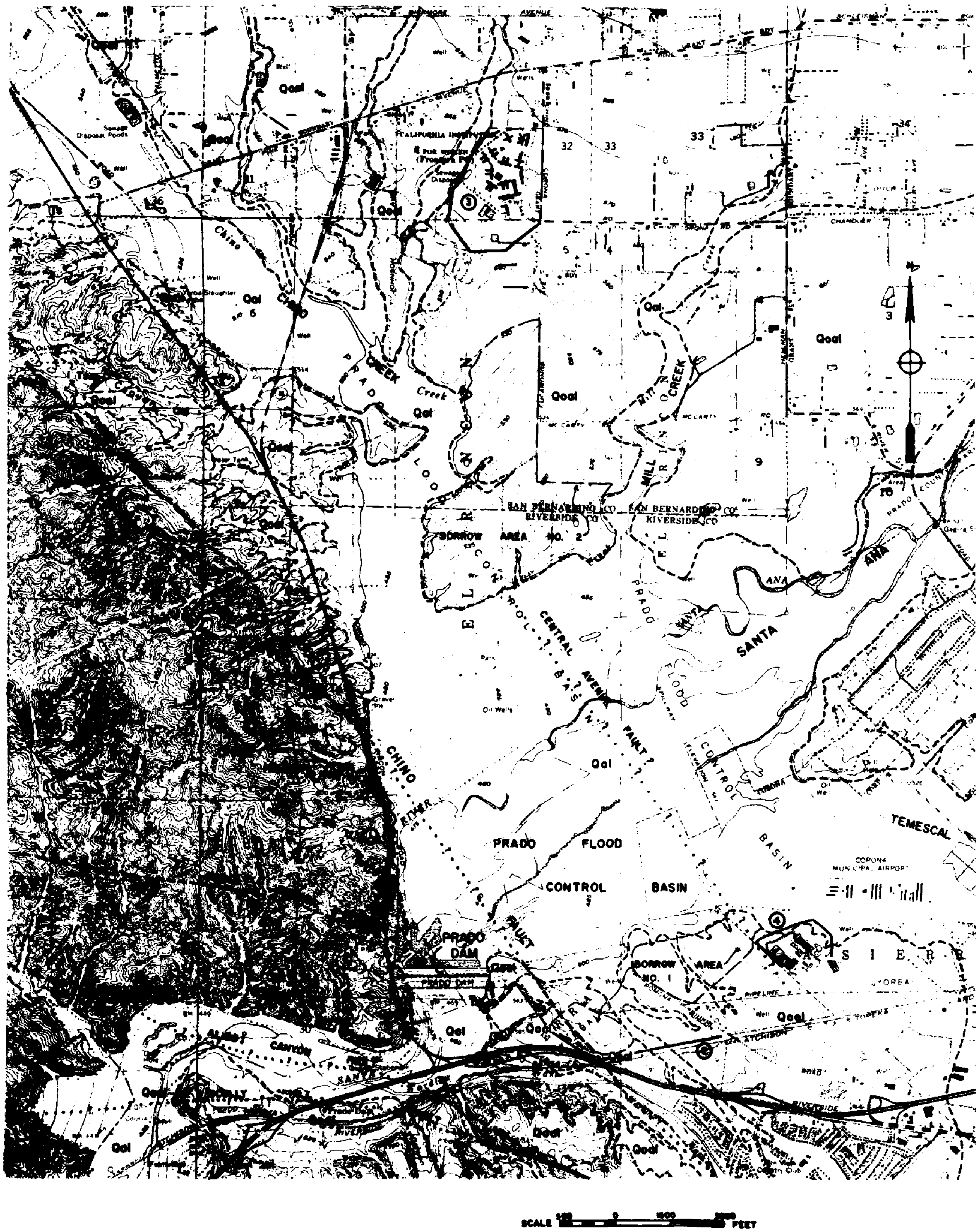
SPEC. NO. DACW09- ___ B-____

DISTRICT FILE NO.

SHEET
OF

PLATE B-2

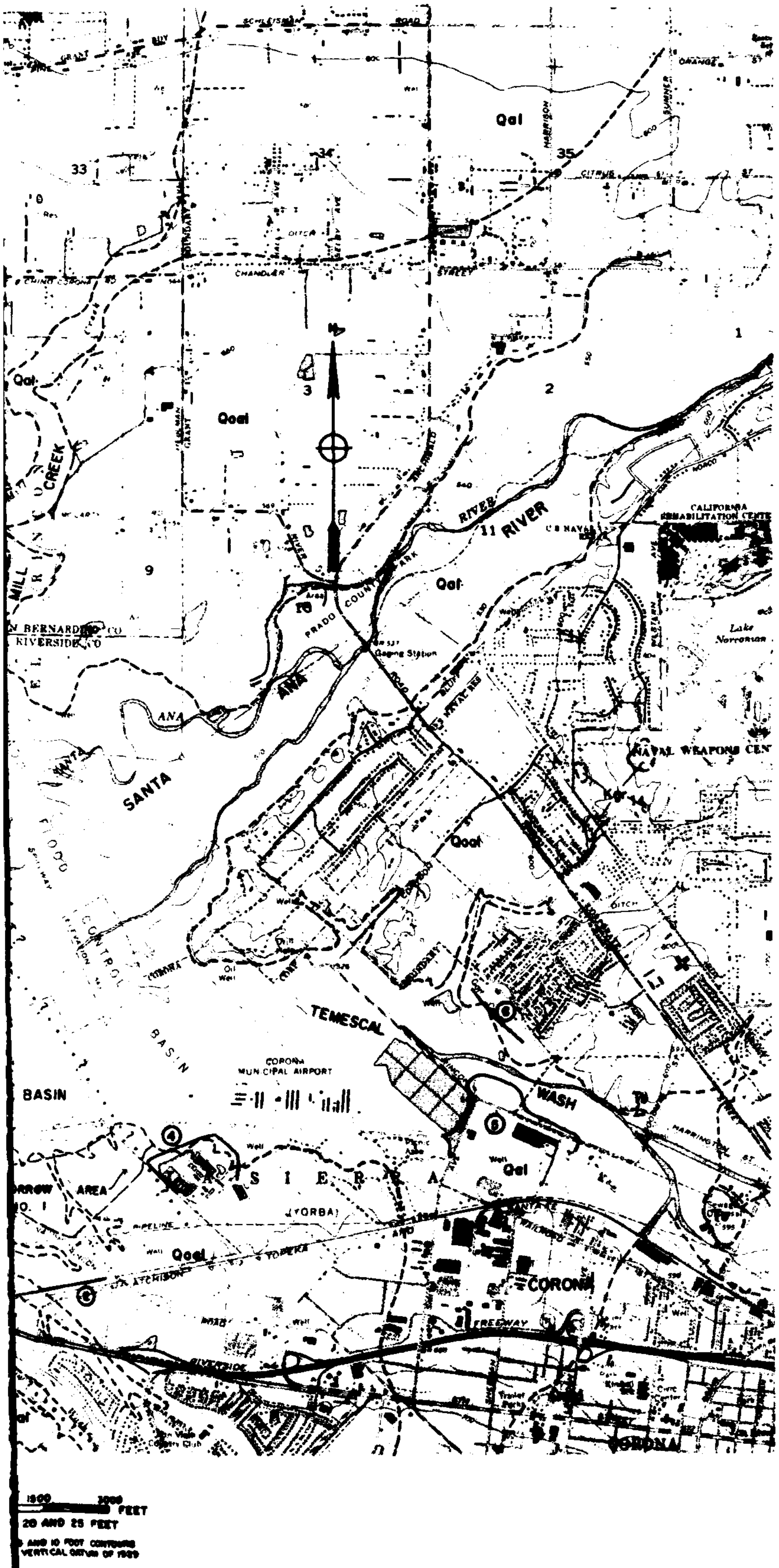
VALUE ENGINEERING P



CONTOUR INTERVALS 20 AND 25 FEET

DOTTED LINES REPRESENT 5 AND 10 FOOT CONTOURS
DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SAFETY PAYS



LEGEND

QUATERNARY

Qal	RECENT ALLUVIUM: Streambed, floodplain, valley fill, and lacustrine deposits
Qoal	PLEISTOCENE ALLUVIUM: Older alluvium, including alluvial terrace and fan deposits

TERTIARY

Ts	EOCENE TO PLIOCENE SEDIMENTS: Undifferentiated; marine and non-marine sandstones, siltstones and conglomerates.

CRETACEOUS

Kgr	BASEMENT COMPLEX: Granitic rocks of the Southern California batholith.

Landslide, arrows indicate direction of movement.

Approximate contact between geologic units queried where conjectural.

Fault, dashed where approximately located, dotted where concealed, queried where conjectural

Syncline, showing direction of plunge of axis, dashed where approximately located

Anticline, dashed where approximately located

DIKES

①	Corona Expressway
②	Auxiliary Dike
③	California Institution for Women
④	Corona Sewage Treatment Plant
⑤	Alcoa Aluminum Plant
⑥	Corona National Housing Tract

NOTES:

1. GEOLOGY MODIFIED FROM DURHAM AND YERKES (1964), ROGERS (1965), MORTON (1974)-IN FIFE AND OTHERS (1976), WEBER (1977), AND WOODWARD-CLYDE CONSULTANTS (1980).
2. BASE MAP FROM U.S.G.S. PRADO DAM AND CORONA NORTH, CA. 7.5' TOPOGRAPHIC MAPS.
3. SEE PLATES 4 THROUGH 7 FOR PRADO DAM DETAILED SITE GEOLOGY.
4. TERTIARY SEDIMENTS (Ts) INCLUDE THE SYCAMORE CANYON MEMBER OF THE PUENTE FORMATION (Tpsc) SHOWN ON PLATES 4 THROUGH 7, AND 52.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

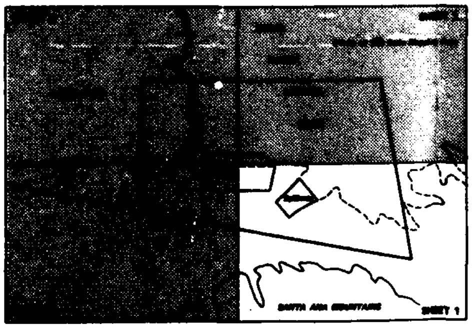
GENERAL GEOLOGY

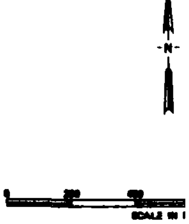
SPEC. NO. DACW09- ___ B- ___

PLATE 9-3

1

2





Orthophotomap Wild Aviogon OR 1
PHOTOGRAPHY DATES JULY 22, 1979 AND AUG 10, 1979

American
AERIAL SURVEYS, INC.

LEGEND

MAPPED UNITS

Fills and Disturbed Areas:

af Artificial fill: compacted embankments for dam, spillway, roads and berms; quarry stockpiles and waste dumps; backfill from construction.

dap Disturbed alluvium: sand and gravel deposits south of dam altered by construction.

dus Disturbed undifferentiated surfaces: areas disturbed by construction or cultivation or otherwise not recognized as associated with other units.

Younger Alluvial Units:

Qyl Young lake deposits: fine grained deposits of recent reservoir sediments.

Qyc Young stream deposits: sands, gravels and associated sediments in active stream channels.

Lower Terrace Deposits:

Qtr Terrace alluvium: brown gravelly silts and sands abandoned above former river channel on the west side of the dam.

Qts Dissected younger silt deposits: low-lying dark brown silts and very fine sands northeast of the spillway and at the mouth of Prado Creek.

Qr_1 Dissected younger fan deposits: red and red-brown silts, fine sands, and poorly bedded gravel deposits, underlies lowest dissected terrace level on upper Prado Creek.

Eolian Deposits:

Qe Gray-brown wind blown silt with scattered sand grains and occasional pebbles.

Paleosol:

S_{xx} Buried pedogenic soil: dark red clayey unit with prominent pedogenic structures and moderate carbonate concentrations near base; xx indicates older alluvial unit on which soil is developed.

Older Alluvial Units:

Qr_2 Older alluvial fan deposits: reddish poorly bedded to well bedded but poorly sorted clayey and silty gravels; massive and weakly bedded gravelly, sandy and clayey silts; exposed in southeast corner of mapped area.

Qo_1 Fine-grained fluvial deposits: silts, clays and clayey very fine sands overlying gravelly sections; distinctive light gray with orange mottling.

Qo_2 Coarse-grained fluvial deposits: gravels, sandy gravels and gravelly silty sands with occasional orange silt interbeds; yellow-gray to orange with rare reddish or black thin layers.

Bedrock:

Tpsc Puente Formation, Sycamore Canyon Member (after Durham and Yerkes, 1964): white, buff and light green feldspathic and conglomeratic sandstones; fairly well bedded to massive with interbedded light bluish gray siltstones.

SYMBOLS

Contact between mapped units, dashed where inferred.

U D 70 Fault: dashed where inferred, dotted where concealed, queried where uncertain; U indicates relatively upthrown side; D indicates downthrown side; dip of fault plane is indicated by arrow.

70E 35 Strike and dip of bedding.

70E 90 Strike of vertical bedding.

70E 45 Strike and dip of shear.

70E 90 Strike of vertical shear

T4 Location of exploratory trench

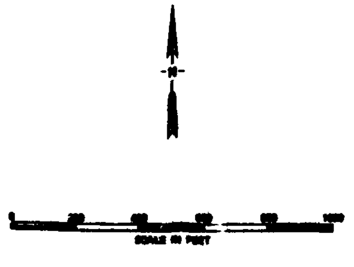
Locations of exploratory boring used in constructing cross sections.

A A' Location of cross section (See Plate 4)

(Qo_1) Parentheses indicate large area probably underlain predominantly by indicated unit but with poor exposures. Outcrops are indicated by conventional symbols.

NOTE

Mapping performed by Woodward-Clyde Consultants in 1980 for the Fault Study Report for Prado Dam.



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SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

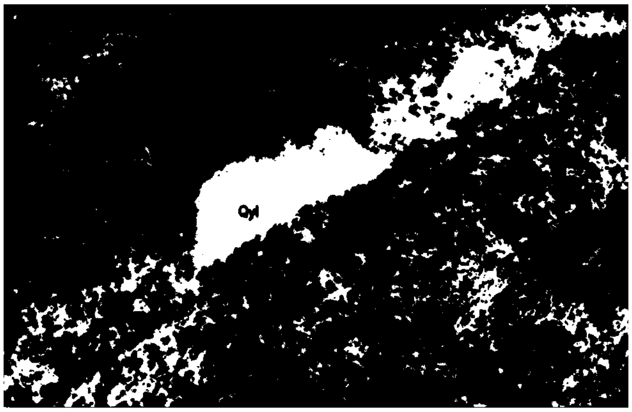
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
SITE GEOLOGY

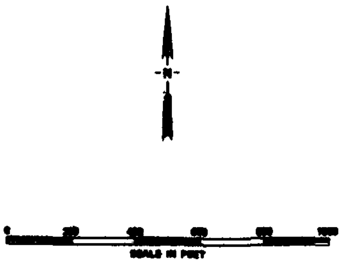
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09- ___ B- ___
DISTRICT FILE NO.
SHEET 1 OF 4

PLATE B-4

2



Explanation of Mapped Units and Symbols are shown on Sheet 1.



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

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CORPS OF ENGINEERS

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PRADO DAM
SITE GEOLOGY

SUBMITTED BY:
DATE APPROVED:
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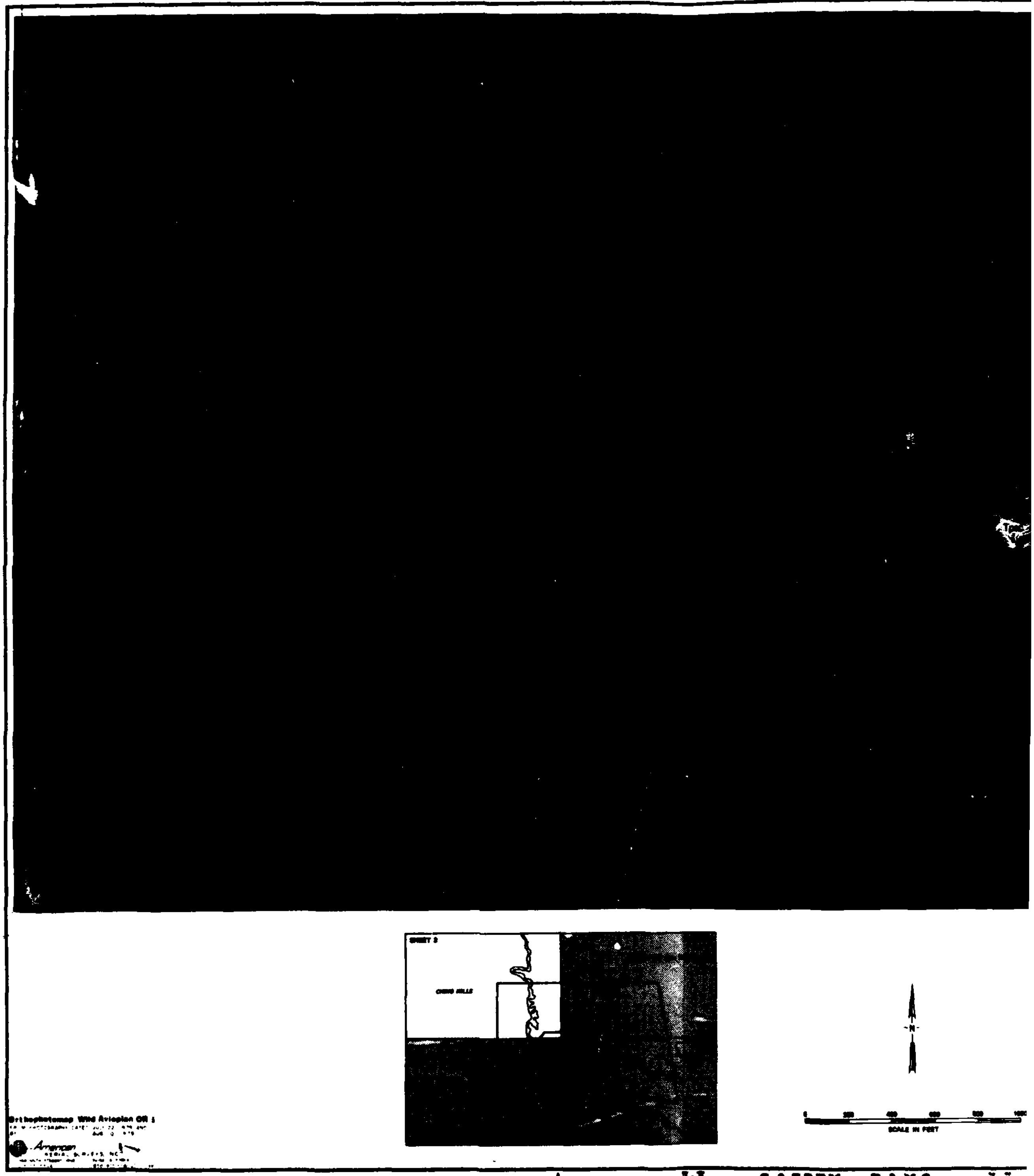
DISTRICT FILE NO.
SHEET 2 OF 4

PLATE B-5

1

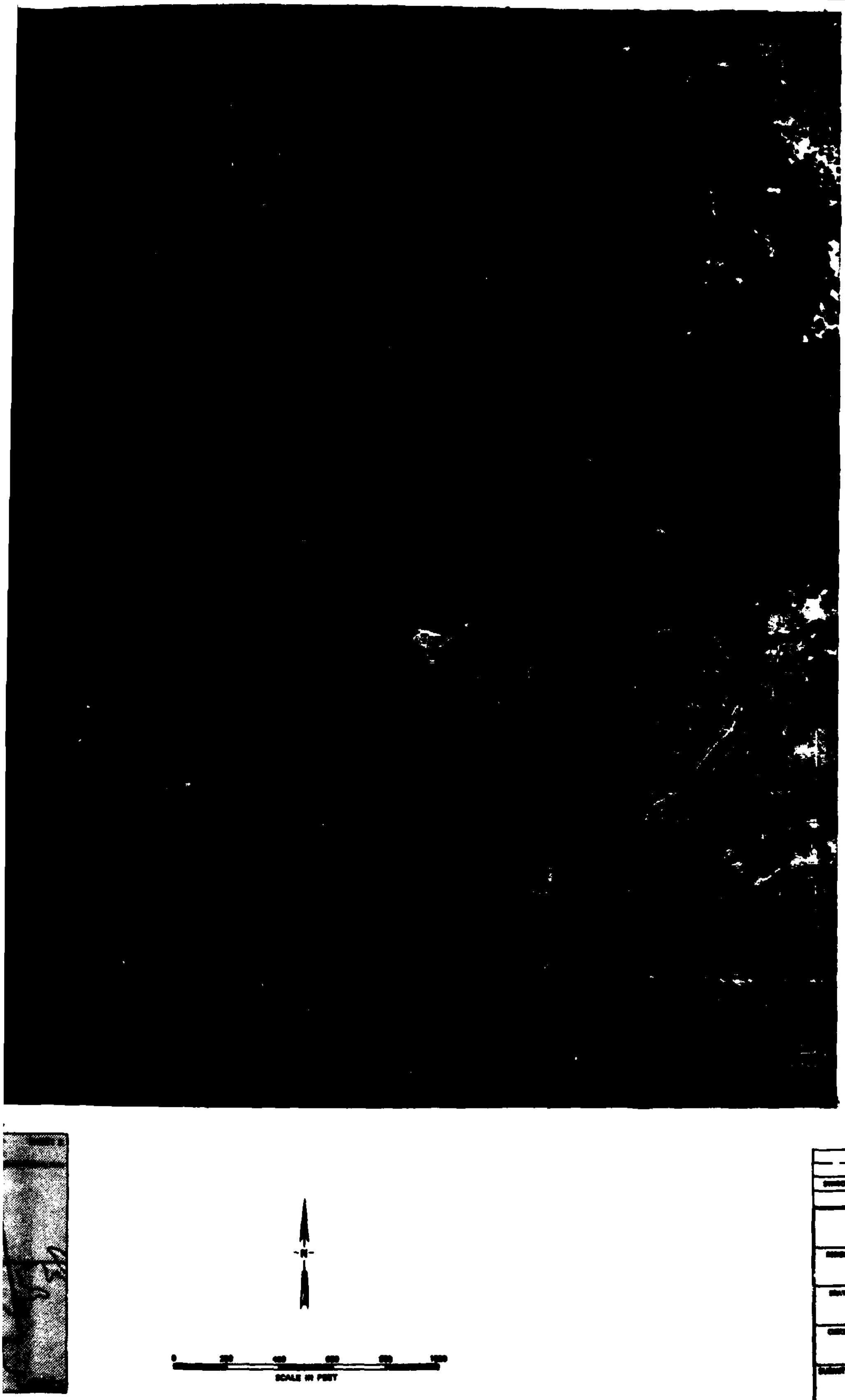
2

VALUE ENGINEERING PAYS



SAFETY PAYS

U S ARMY



Explanation of Mapped Units and Symbols are Shown on Sheet 1

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

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CORPS OF ENGINEERS

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PRADO DAM
SITE GEOLOGY

SUBMITTED BY:
DATE APPROVED:
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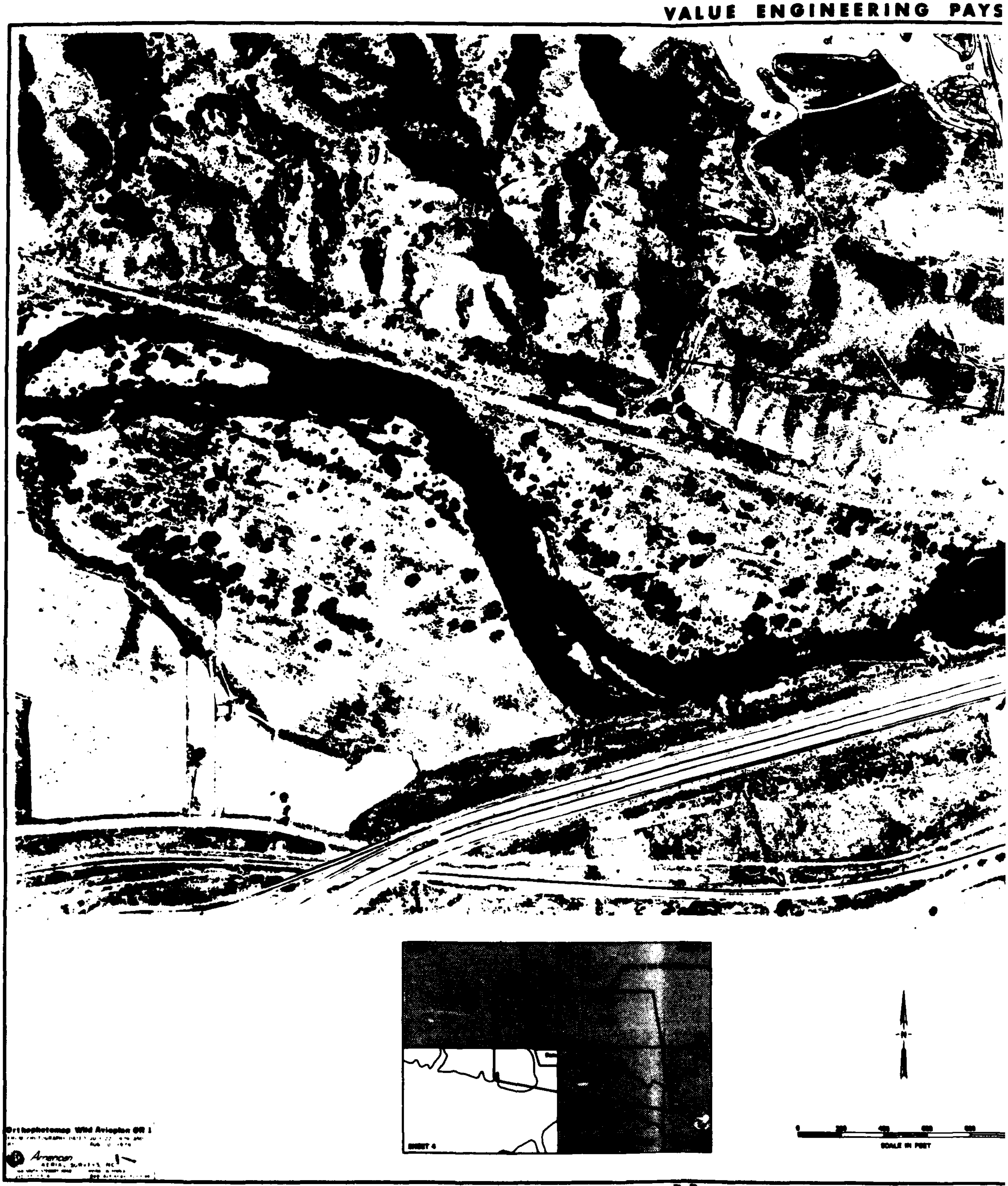
SHEET 3 OF 4

PLATE B-6

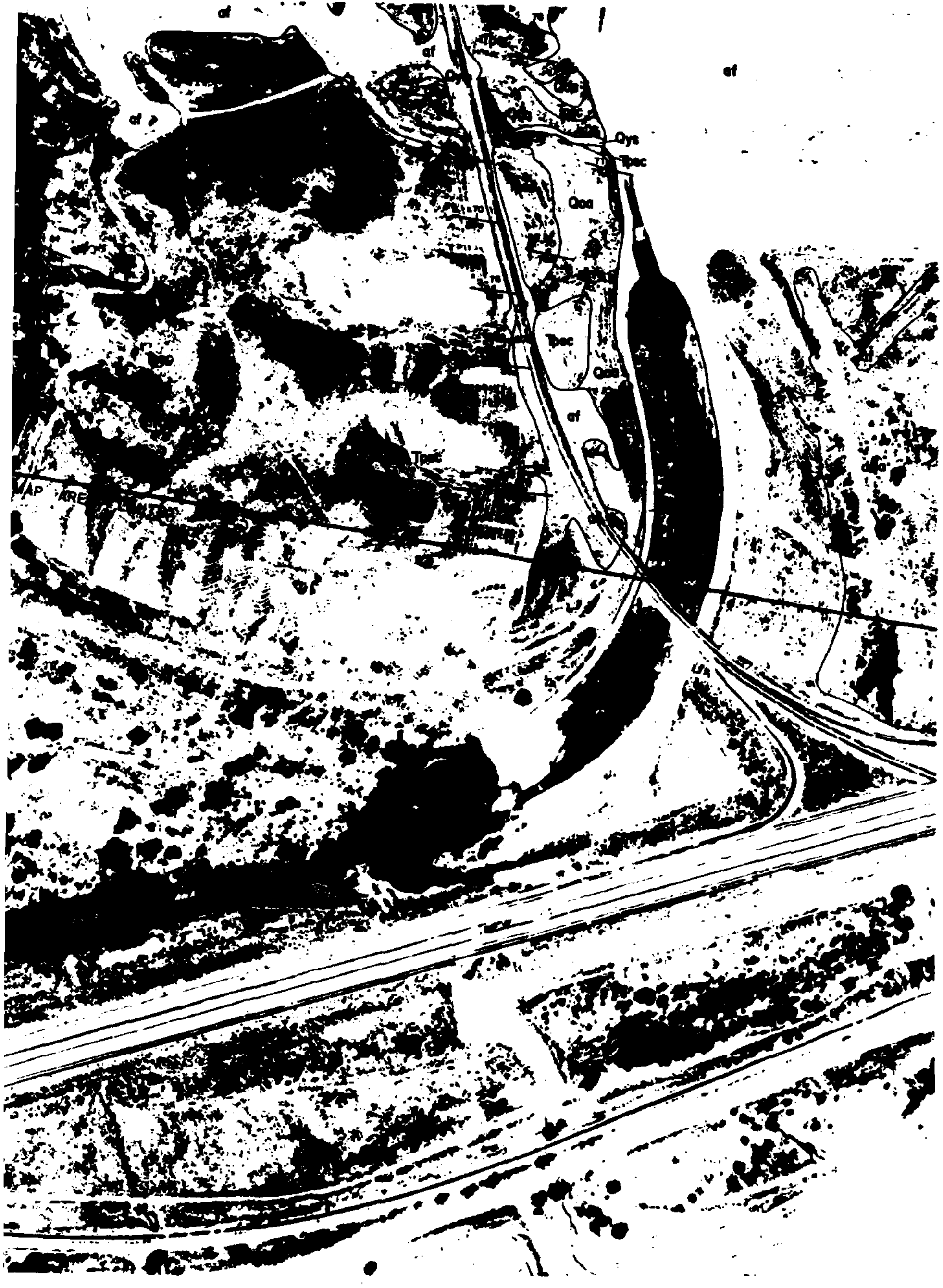
1

2

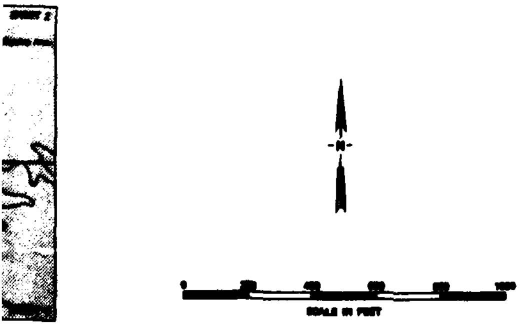


Orthophotomap Wild Avioplan OR 1

American
AERIAL SURVEYS, INC



Explanation of Mapped Units and Symbols are Shown on Sheet 1.



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

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CORPS OF ENGINEERS

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PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
SITE GEOLOGY

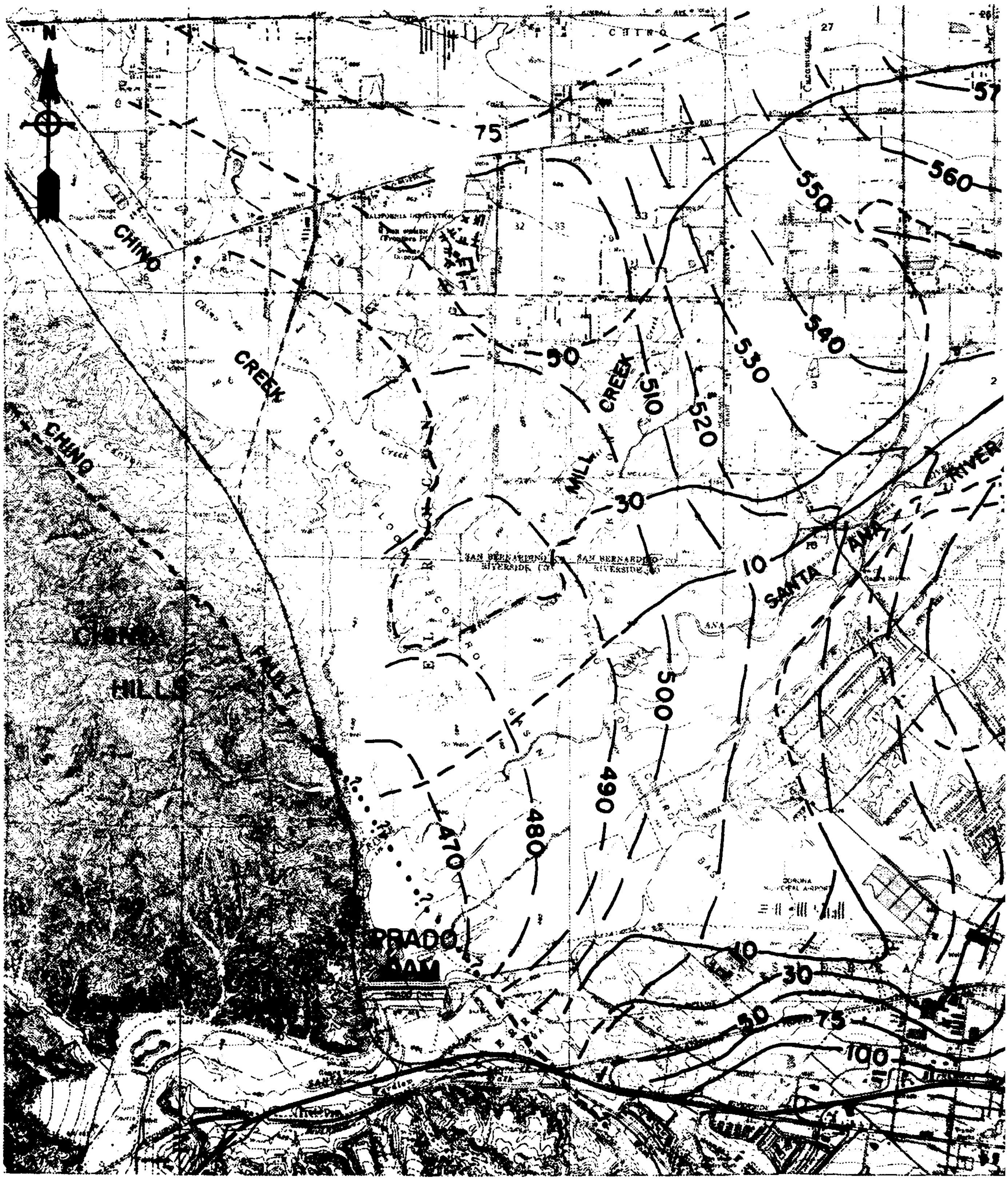
SUBMITTED BY
DATE APPROVED
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET 4 OF 4

PLATE B-7

1

2

U.S. ARMY ENGINEER DISTRICT

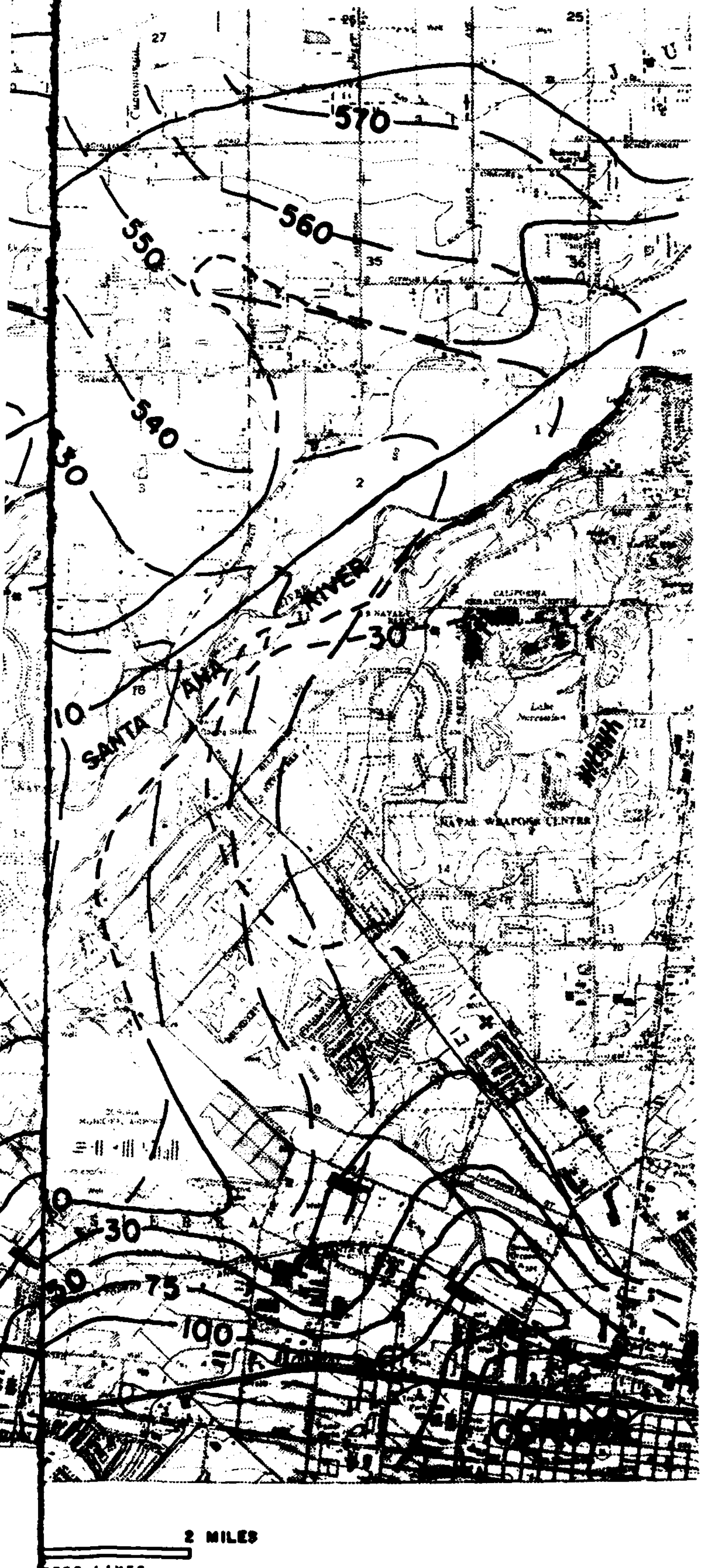


SCALE 1:48000

½ 0 1 2 MILES

CONTOUR INTERVALS 20 AND 25 FEET. DOTTED LINES REPRESENT 5-AND 10-FOOT CONTOURS.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929



TTED LINES

TUM OF 1929

LEGEND

—— 10 — —	CONTOUR LINE SHOWING MINIMUM DEPTH TO GROUNDWATER DURING 1973–1979 PERIOD, DASHED WHERE APPROXIMATELY LOCATED, DEPTH IN FEET BELOW LAND SURFACE.
—— 500 ——	CONTOUR LINE SHOWING APPROXIMATE GROUNDWATER ELEVATION IN FEET.
— — • • ? • •	FAULT, DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE CONCEALED, QUERIED WHERE UNCERTAIN.

NOTES:

1. MINIMUM DEPTH TO GROUNDWATER CONTOURS FROM CARSON AND MATTI (1985).
2. GROUNDWATER ELEVATION CONTOURS DERIVED FROM PUBLISHED SOURCES AND CORPS OF ENGINEERS FIELD INVESTIGATIONS.
3. SEE PLATE 1 FOR LOCATION OF VARIOUS PROJECT FEATURES.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

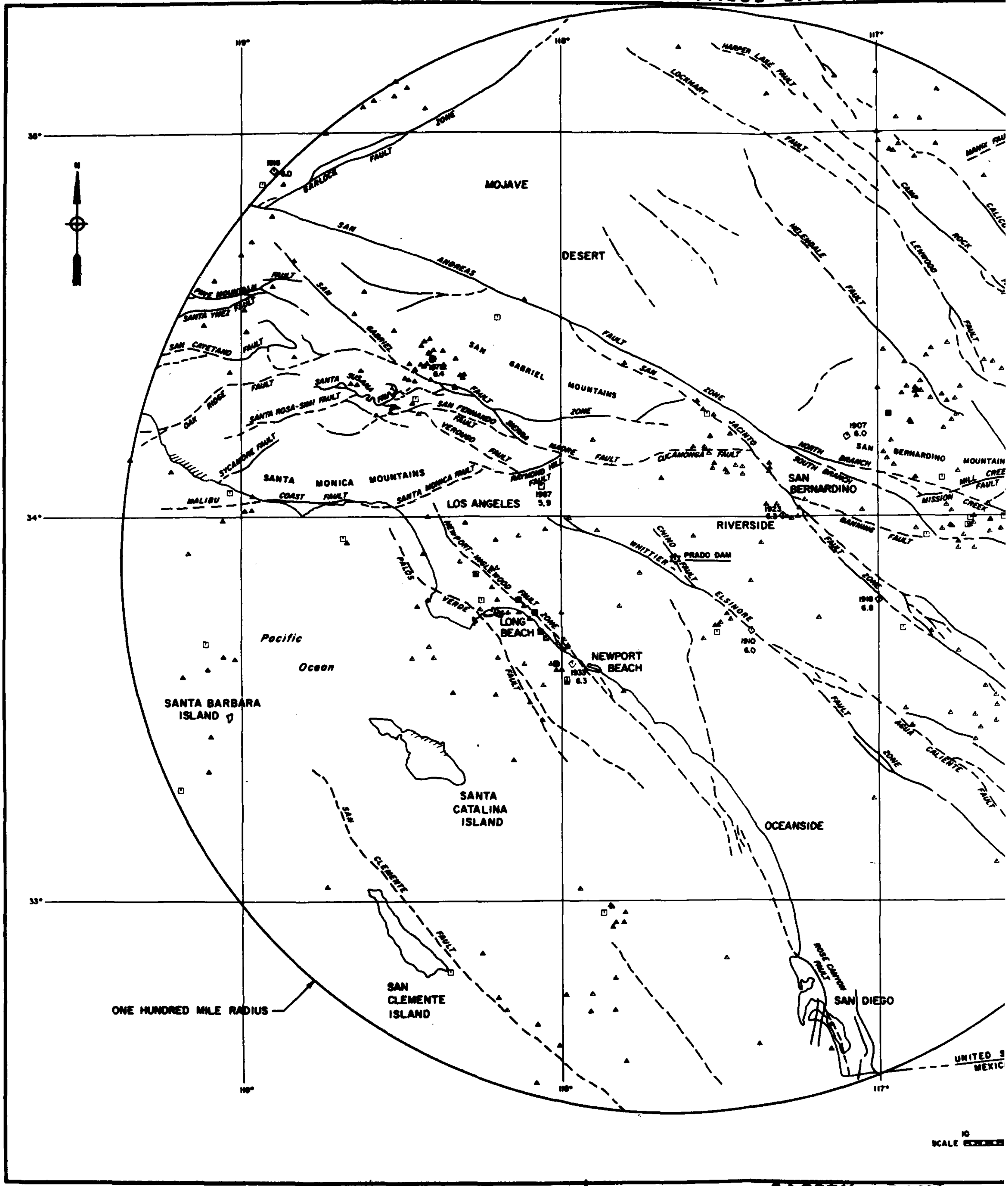
PRADO DAM

GROUNDWATER CONTOURS

SPEC. NO. DACW09-____B-____

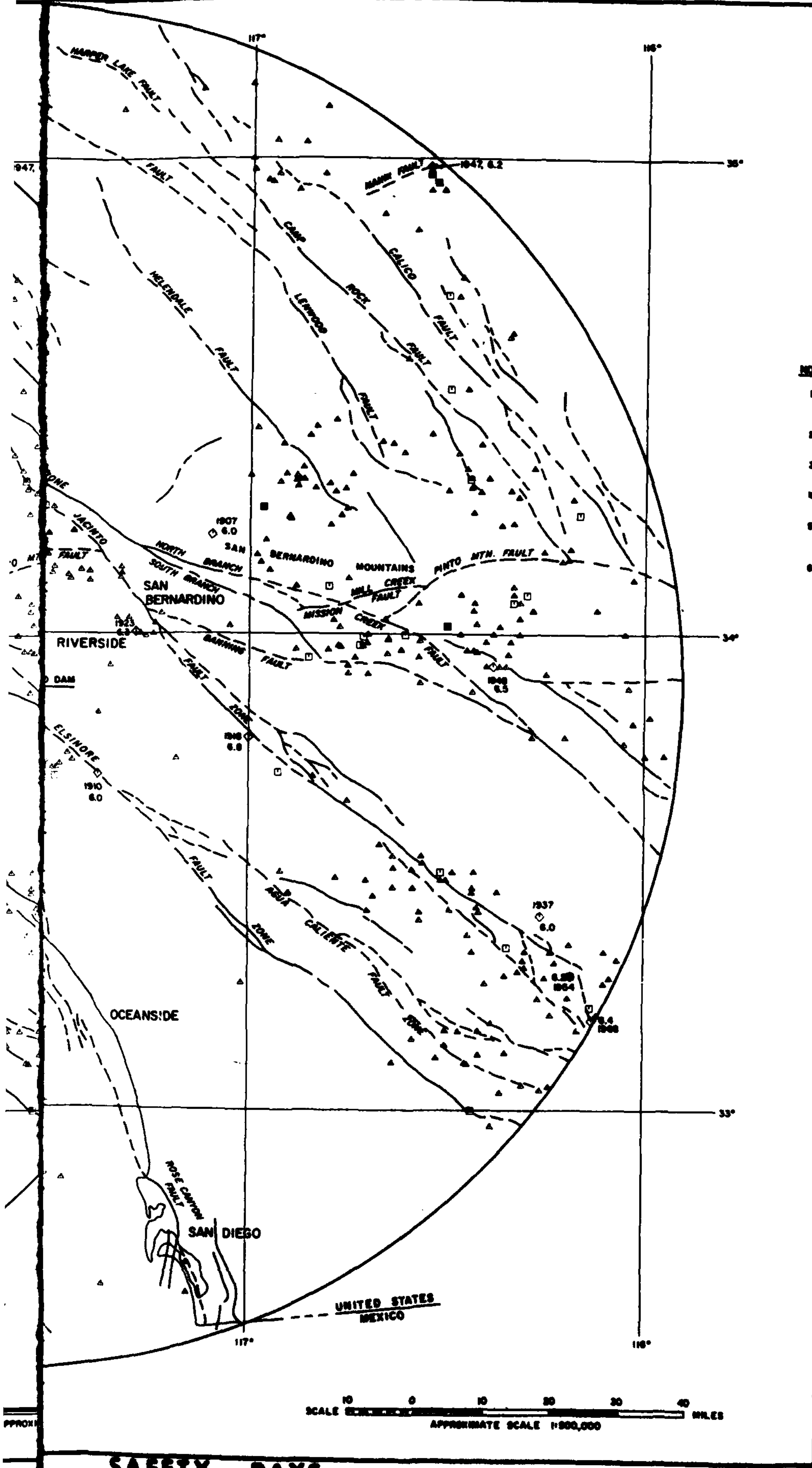
DISTRICT FILE NO.

PLATE B-2



119°
118°
117°
36°
34°
33°
N
MOJAVE
DESERT
GARLOCK FAULT ZONE
HARPER LAKE FAULT
LOCKHART FAULT
CAMP ROCK
LENWOOD FAULT
HELENDALE FAULT
MANIX FAULT
CALICO
SAN ANDREAS FAULT ZONE
PINE MOUNTAIN FAULT
SANTA YNEZ FAULT
SAN CAYETANO FAULT
OAK RIDGE FAULT
SANTA SUSANA FAULT
SANTA ROSA-SIMI FAULT
SAN GABRIEL FAULT
SAN GABRIEL MOUNTAINS
SAN FERNANDO FAULT
VERDUGO FAULT
SIERRA MADRE FAULT ZONE
SAN JACINTO FAULT ZONE
CUCAMONGA FAULT
SYCAMORE FAULT
RAYMOND HILL FAULT
SANTA MONICA MOUNTAINS
SANTA MONICA FAULT
MALIBU COAST FAULT
1971 6.4
1916 6.0
1907 6.0
1967 3.9
1923 6.3
1918 6.8
1910 6.0
1933 6.3
LOS ANGELES
SAN BERNARDINO
SAN BERNARDINO MOUNTAIN
NORTH BRANCH
SOUTH BRANCH
MILL CREEK FAULT
MISSION CREEK
BANNING FAULT
RIVERSIDE
CHINO FAULT
WHITTIER FAULT
ELSINORE FAULT ZONE
PRADO DAM
NEWPORT-INGLEWOOD FAULT ZONE
PALOS VERDES FAULT
LONG BEACH
NEWPORT BEACH
Pacific Ocean
SANTA BARBARA ISLAND
SANTA CATALINA ISLAND
SAN CLEMENTE FAULT
SAN CLEMENTE ISLAND
AGUA CALIENTE FAULT ZONE
OCEANSIDE
ROSE CANYON FAULT
SAN DIEGO
UNITED S
MEXIC
ONE HUNDRED MILE RADIUS
10
SCALE

ALUE ENGINEERING PAYS



LEGEND

- ▲ EARTHQUAKE WITH MAGNITUDE 4.0 THRU 4.99
- ☐ EARTHQUAKE WITH MAGNITUDE 5.0 THRU 5.99
- ◇ EARTHQUAKE WITH MAGNITUDE 6.0 THRU 6.99
- ✡ LOCATION OF PROJECT AREA
- ⟋ TRACE OF FAULT DASHED WHERE INFERRED OR CONCEALED

NOTES:

1. Richter scale magnitudes are a measure of the energy released at the focus (center of the earthquake) as determined by the amplitudes produced on a seismogram.
2. The epicenter is the point on the earth's surface directly above the focus.
3. Earthquake epicenters plotted are from 1932 to 1987, unless earlier dates are shown.
4. Base map modified from state of California (South Half) 1:500,000 topographic map; United States Geological Survey, 1981.
5. Locations of faults are approximate. Data derived from various California Division of Mines and Geology and United States Geological Survey publications.
6. Earthquake epicenter locations are from California Institute of Technology's seismologic data base for Southern California, Nevada, and Arizona; from Toppozada and others (1981), and from Toppozada and Parke (1982).

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: RLT
DRAWN BY: J.T.B.
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
EARTHQUAKE EPICENTER AND FAULT
LOCATION MAP

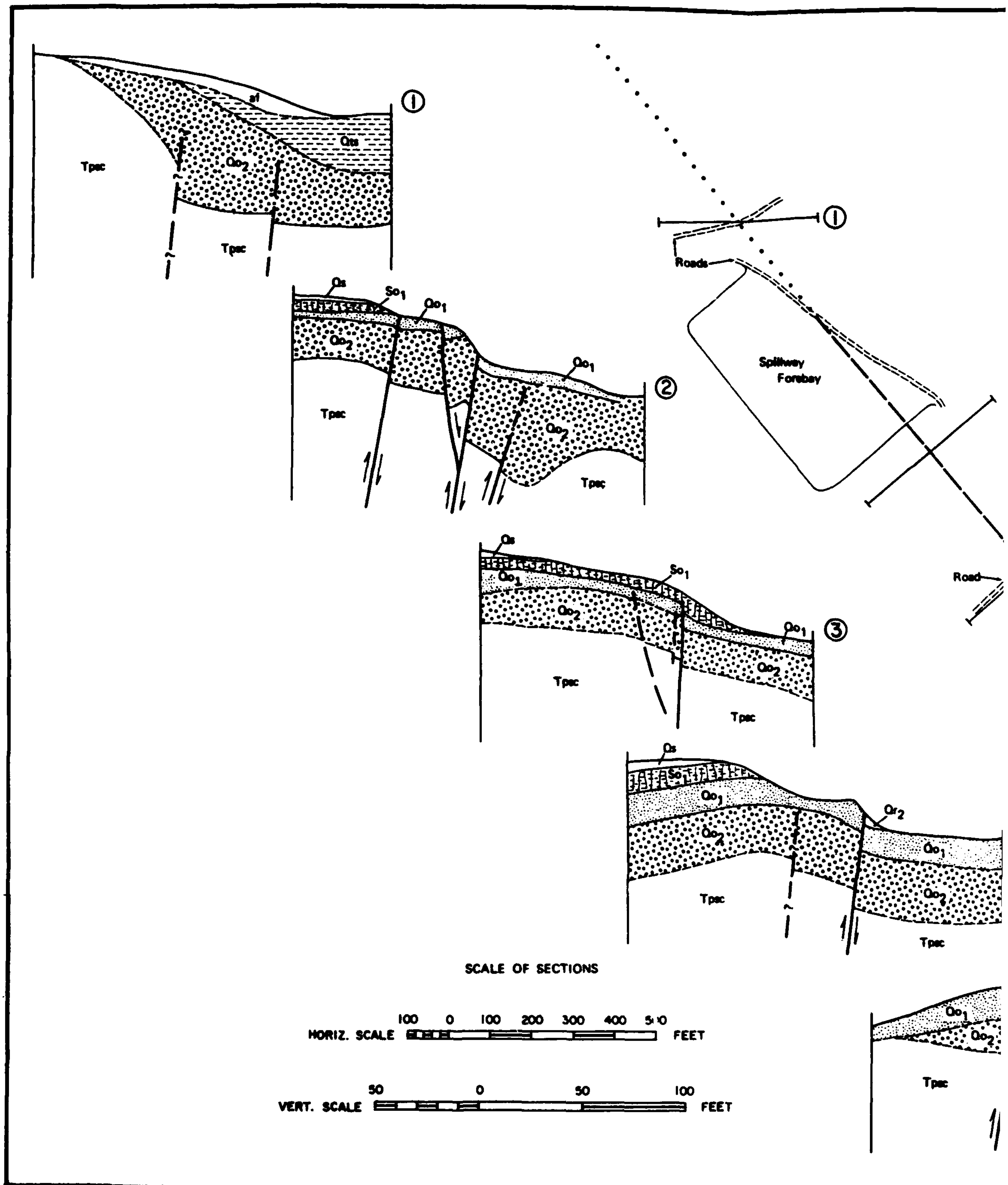
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-6

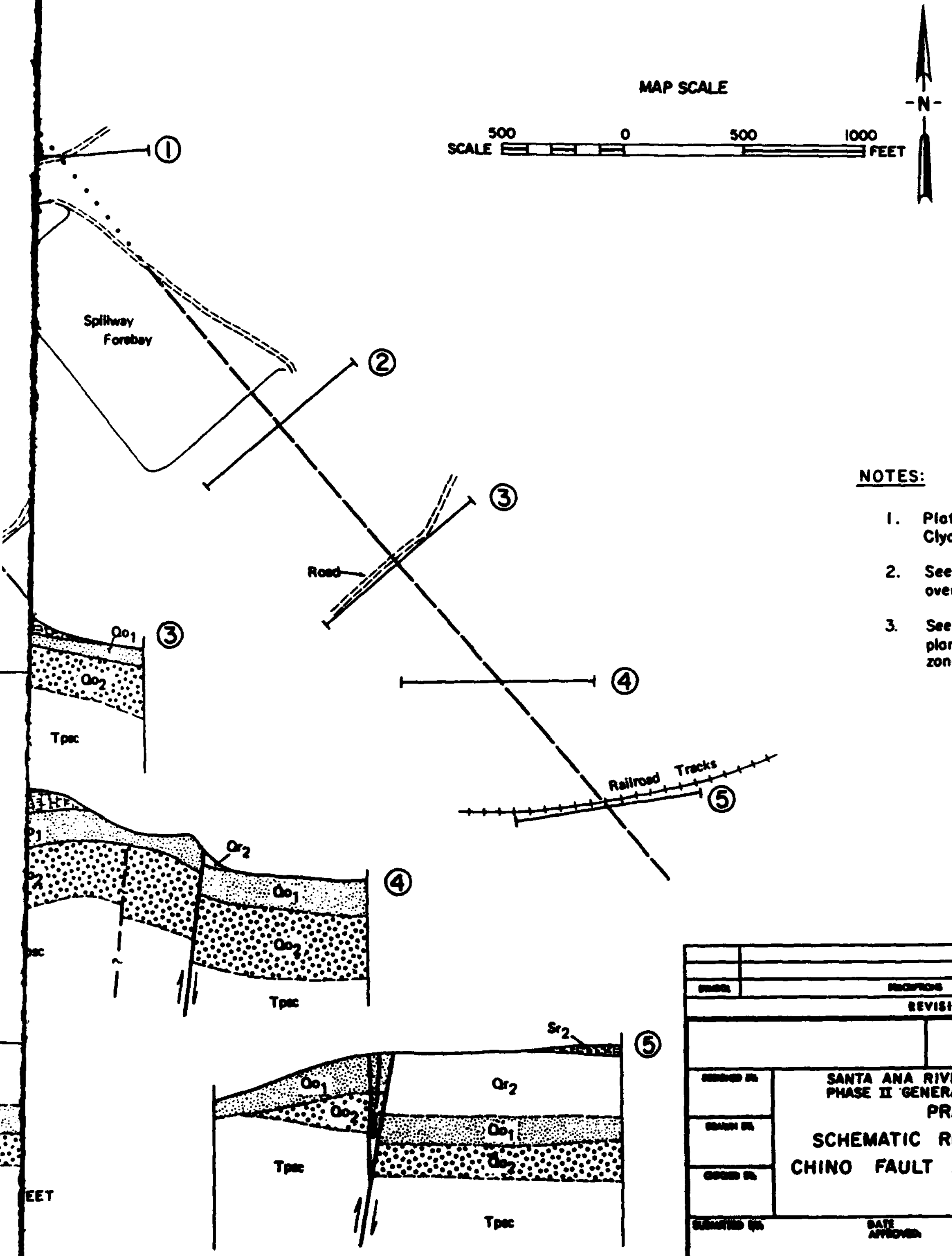
SAFETY PAYS

1

2



①
Tpsc
sl
Qo_2
Qts
Tpsc
Qs
So_1
Qo_1
Qo_2
Qo_1
②
Tpsc
Qo_2
Tpsc
①
Roads
Spillway
Forebay
Qs
So_1
Qo_1
Qo_2
Qo_1
③
Qo_2
Tpsc
Tpsc
Road
Qs
So_1
Qo_1
Qr_2
Qo_2
Qo_1
Qo_2
Tpsc
Tpsc
Qo_1
Qo_2
Tpsc
SCALE OF SECTIONS
HORIZ. SCALE
100 0 100 200 300 400 500
FEET
VERT. SCALE
50 0 50 100
FEET



NOTES:

1. Plate modified from Woodward-Clyde Consultants (1980).
2. See plate 4 for description of overburden and bedrock units.
3. See plate 52 for outlet works plan and location of Chino fault zone.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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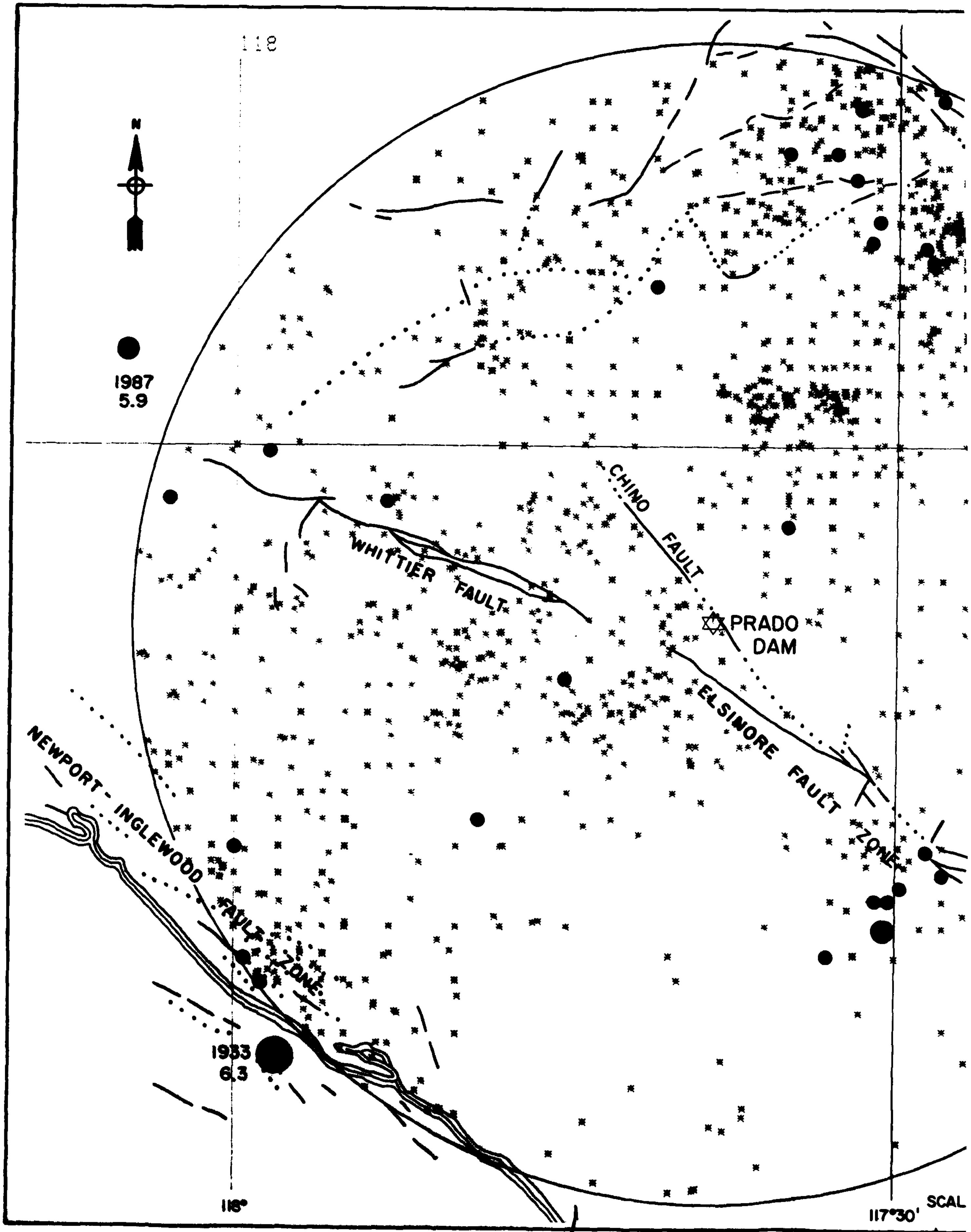
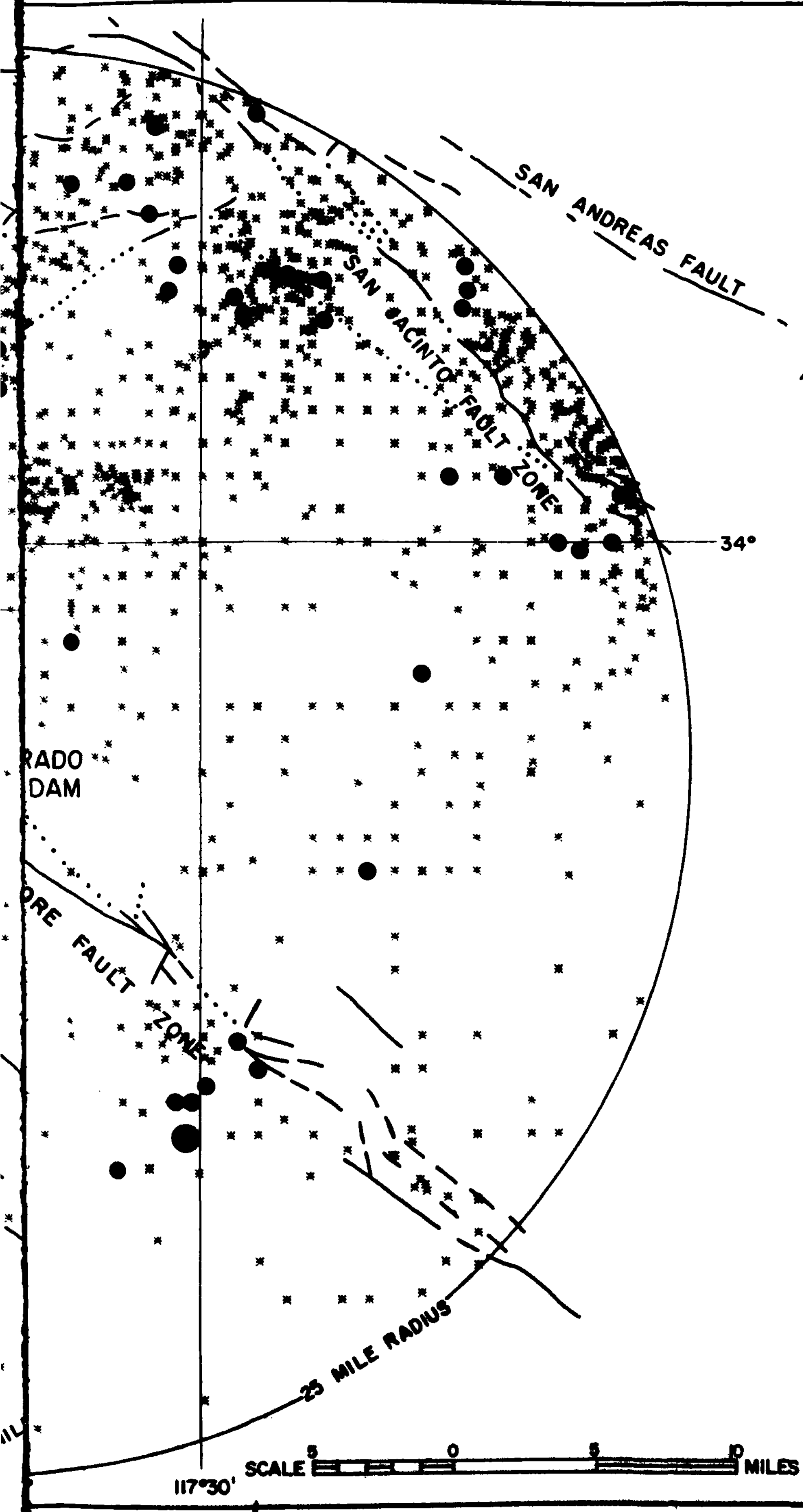
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM
PRADO DAM
SCHEMATIC REPRESENTATION OF
CHINO FAULT ZONE NEAR SPILLWAY

SUBMITTED BY
DATE APPROVED
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET

PLATE B-10


N
1987
5.9
WHITTIER FAULT
CHINO FAULT
PRADO
DAM
ELSINORE FAULT ZONE
NEWPORT - INGLEWOOD FAULT ZONE
1933
6.3
118°
117°30'
SCAL



LEGEND

✱	EARTHQUAKE WITH MAGNITUDE LESS THAN 4.0
●	EARTHQUAKE WITH MAGNITUDE 4.0 THROUGH 4.9
●	EARTHQUAKE WITH MAGNITUDE 5.0 THROUGH 5.9
●	EARTHQUAKE WITH MAGNITUDE 6.0 THROUGH 6.9
--··	TRACE OF FAULT, DASHED WHERE APPROXIMATELY LOCATED, DOTTED WHERE INFERRED OR CONCEALED

NOTES:

1. EARTHQUAKES SHOWN REPRESENT ALL EVENTS WITH RICHTER MAGNITUDES EQUAL TO OR GREATER THAN 2.0 WITHIN 25 MILES OF PRADO DAM DURING THE PERIOD 1932 THROUGH 1987.
2. EARTHQUAKE EPICENTER LOCATIONS ARE FROM CALIFORNIA INSTITUTE OF TECHNOLOGY'S SEISMOLOGIC DATA BASE FOR SOUTHERN CALIFORNIA, NEVADA, AND ARIZONA.
3. FAULT TRACES DEPICTED REPRESENT FAULTING WITH EVIDENCE OF POST-TERTIARY ACTIVITY AS SHOWN ON FAULT MAP OF CALIFORNIA COMPILED BY JENNINGS (1975).

REVISIONS

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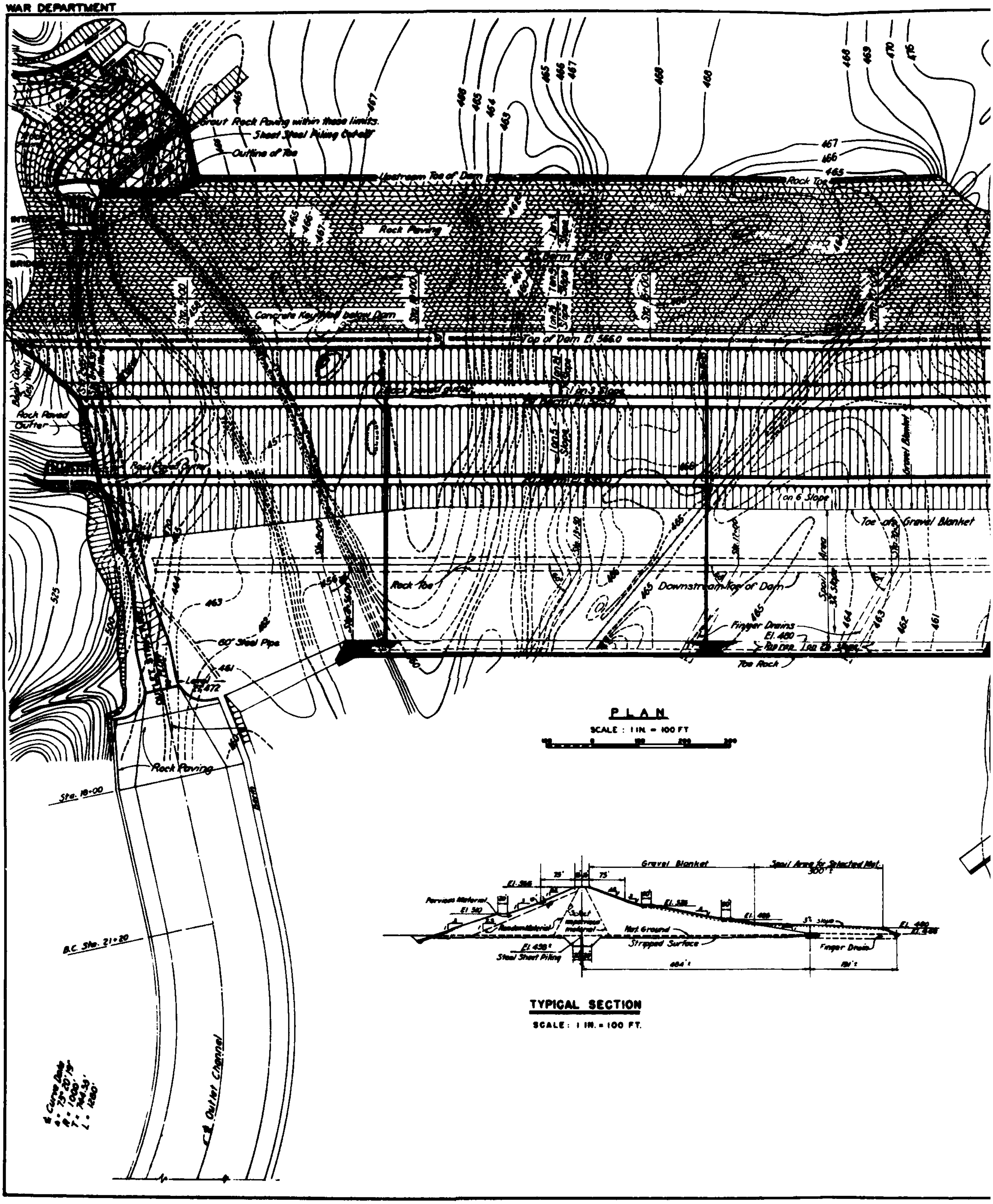
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
LOCAL SEISMICITY

WAR DEPARTMENT

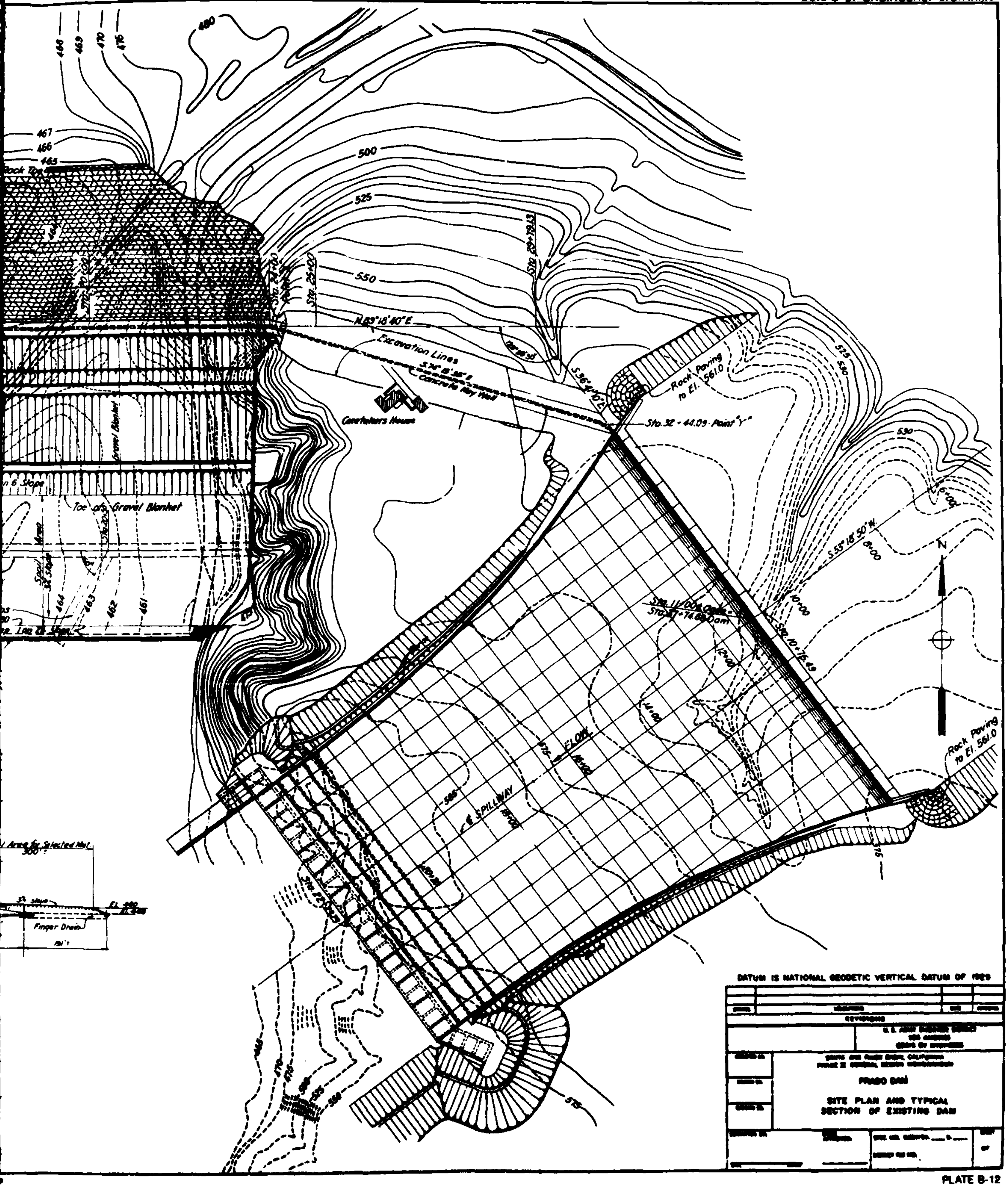


PLAN

SCALE: 1 IN. = 100 FT

TYPICAL SECTION

SCALE: 1 IN. = 100 FT.



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LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

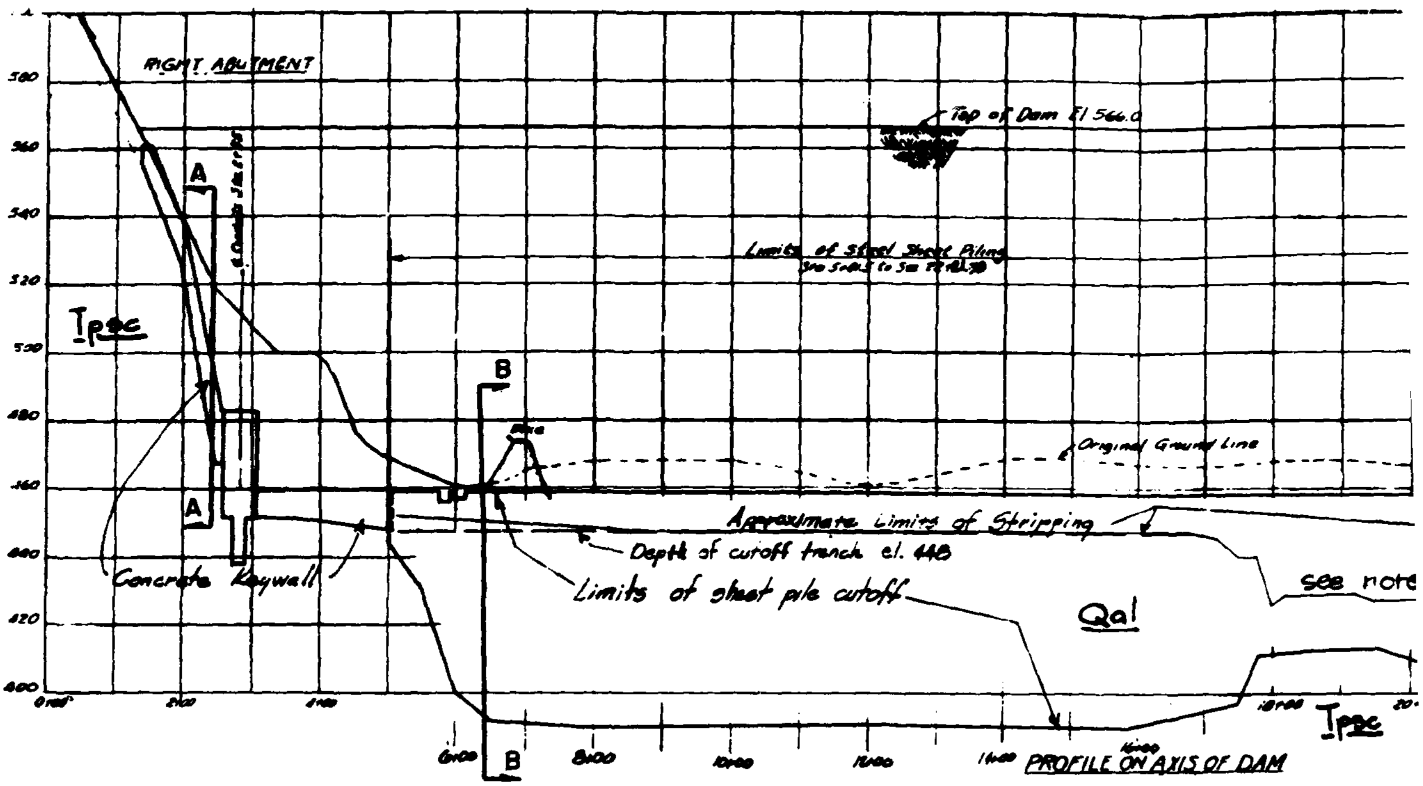
PRADO DAM

SITE PLAN AND TYPICAL
SECTION OF EXISTING DAM

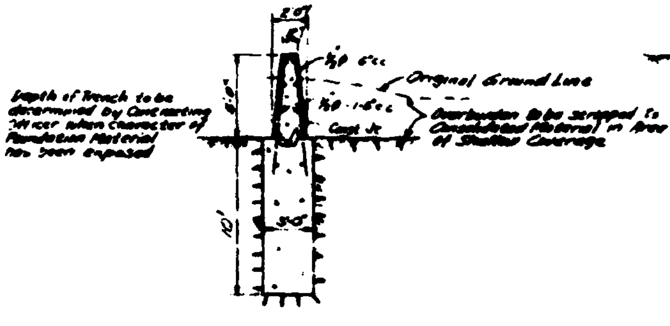
PLATE B-12

1

2



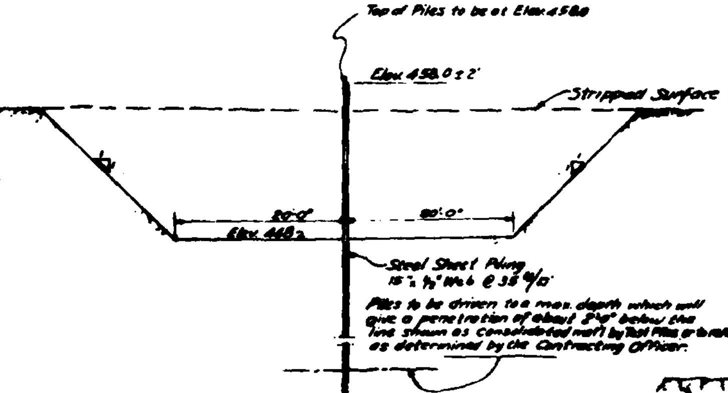
PROFILE ON AXIS OF DAM



Depth of Trench to be determined by Contracting Officer when character of Foundation Material has been exposed

Overburden to be stripped to Consolidated Material in Area of Shallow Coverage

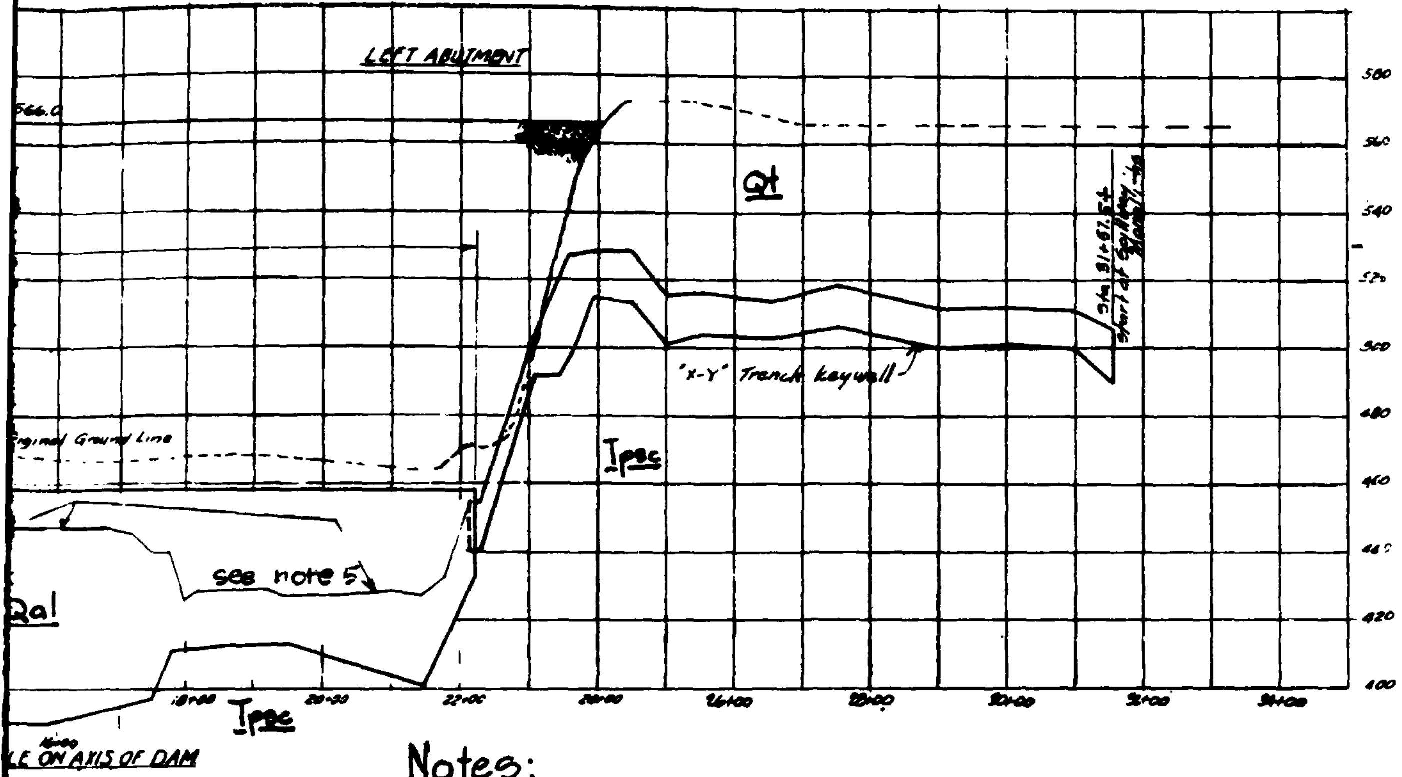
SECTION A-A



Piles to be driven to a max. depth which will give a penetration of about 2'-0" below the line shown as consolidated mat'l by Test Piles or borings as determined by the Contracting Officer.

SECTION B-B

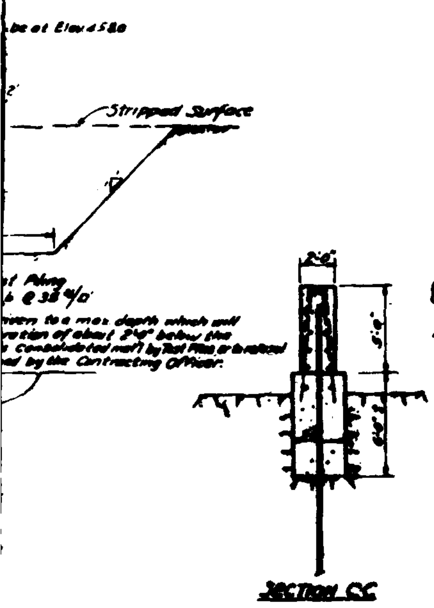
SECTION



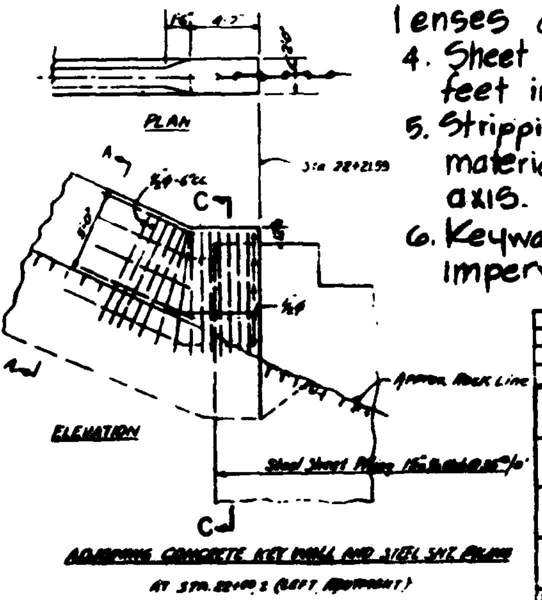
LE ON AXIS OF DAM

Notes:

1. Qal = Recent alluvium consists of gravelly sand & clay lenses.
2. Qt = Terrace alluvium; consists of loose to dense silts, sands, gravel, and cobbles.
3. Tpsc = Puente formation; Sycamore Canyon member (Lower Pliocene); consists of slight to moderate cemented sandstone w/ siltstone interbeds and scattered lenses of conglomerate.
4. Sheet piling was driven from 2 to 3 feet into bedrock.
5. Stripping line indicates depth of materials removed upstream of the axis.
6. Keywall trench backfilled w/ select impervious material.



SECTION CC



ADJOINING CONCRETE KEY WALL AND STEEL SHT PILING

AT STA. 22+00 ± (LEFT ABUTMENT)

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U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

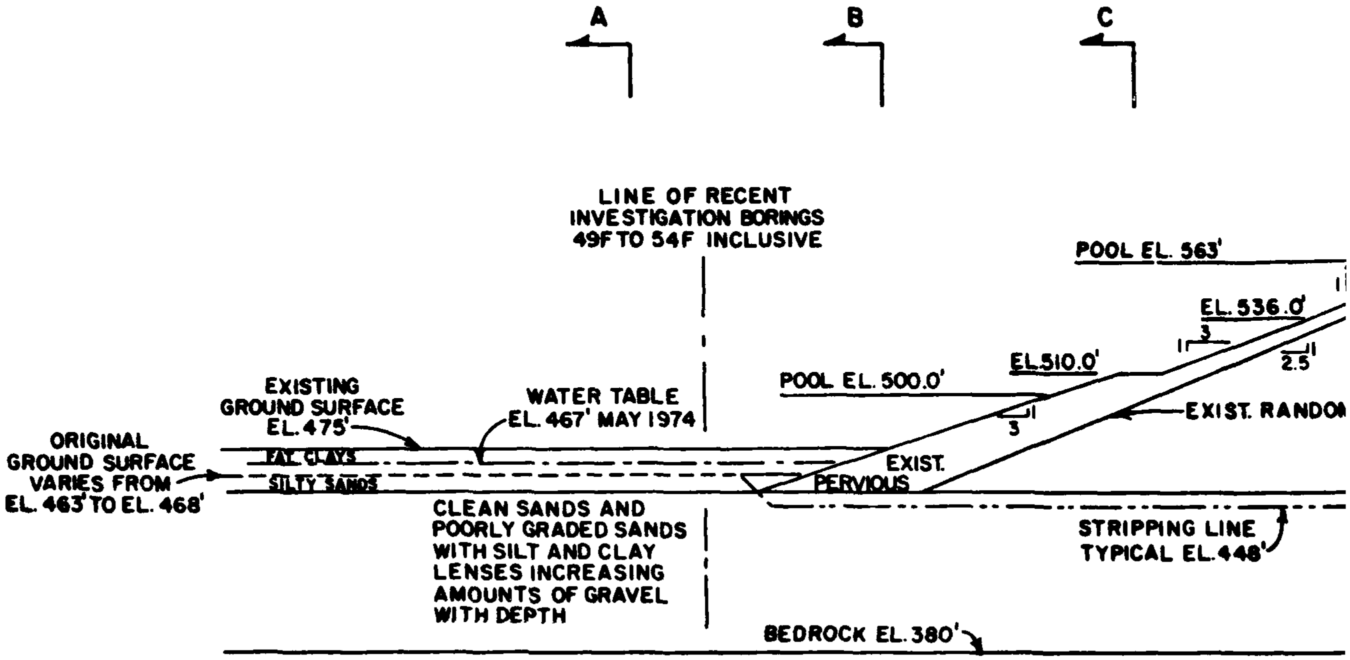
AS CONSTRUCTED
FOUNDATION TREATMENT

SPEC. NO. DACW09-___-B-____

DISTRICT FILE NO.

1

2

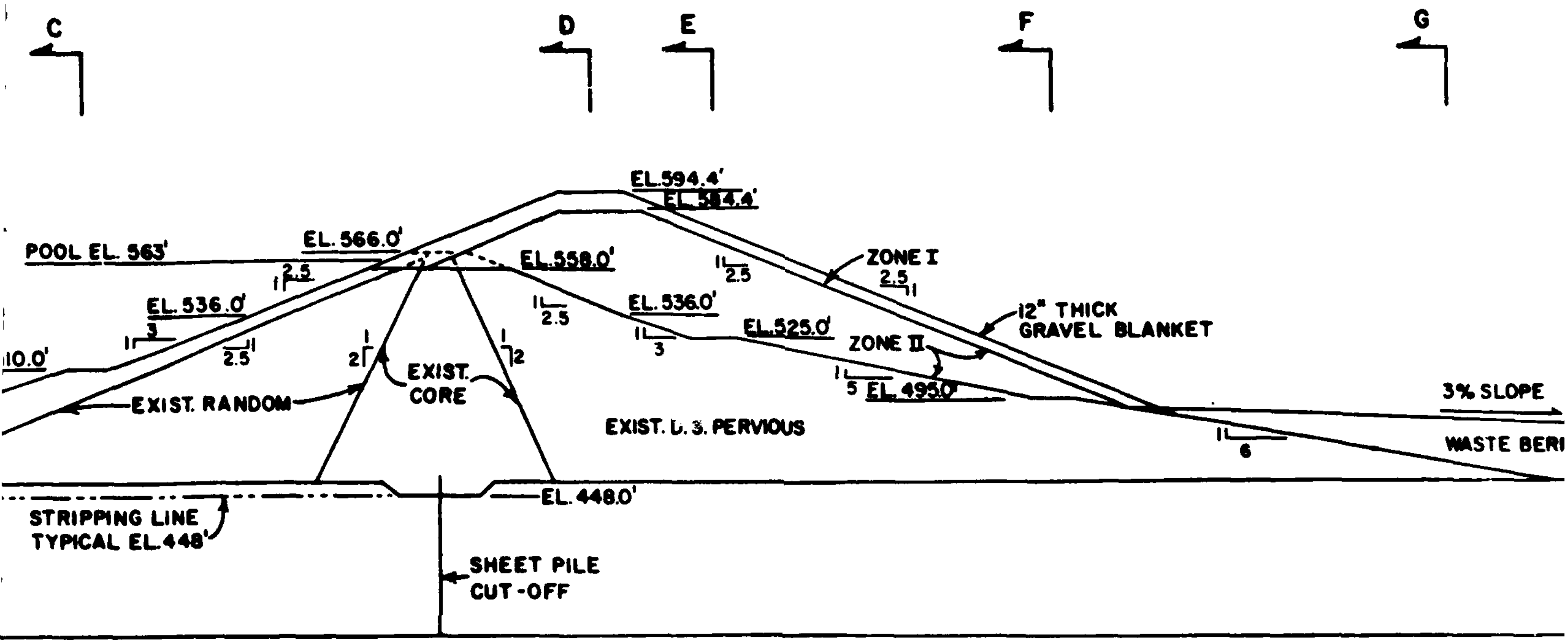


NOTE

FOR PURPOSES OF ANALYSIS THE WATER TABLE WAS ASSUMED TO BE AT THE EXISTING GROUND SURFACE.

MATERIAL

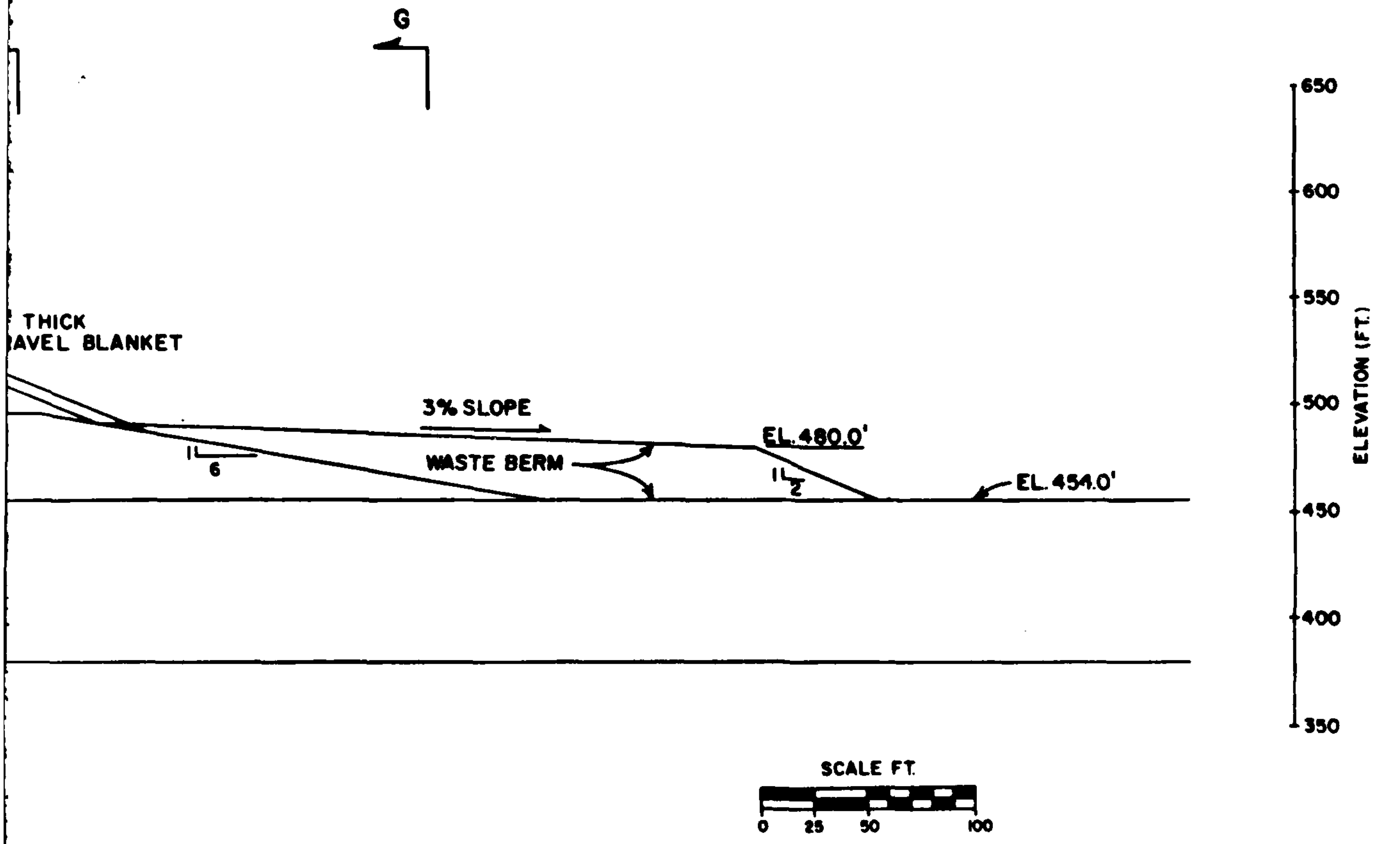
U. S. PERV
RANDO
CORE
D. S. PERV



TYPICAL SECTION

COMPACTION DATA
EXISTING EMBANKMENT

MATERIAL TYPE	COMPACTIVE EFFORT ON 6 INCH LIFTS NO. OF PASSES	COMPACTIVE EFFORT ON 6 INCH LIFTS EQUIPMENT TYPE	AVG. DRY DENSITY (PCF)	AVG. MOISTURE (PERCENT)
U. S. PERVIOUS	4-6	DRUM ROLLER	130.1	9.3
RANDOM	8	SHEEPSFOOT ROLLER	124.5	10.9
CORE	8	SHEEPSFOOT ROLLER	118.6	12.9
D. S. PERVIOUS	4-6	DRUM ROLLER	127.4	9.8



AVG. MOISTURE (PERCENT)
9.3
10.9
12.9
9.8

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PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

TYPICAL EMBANKMENT SECTION

SUBMITTED BY:
DATE APPROVED:
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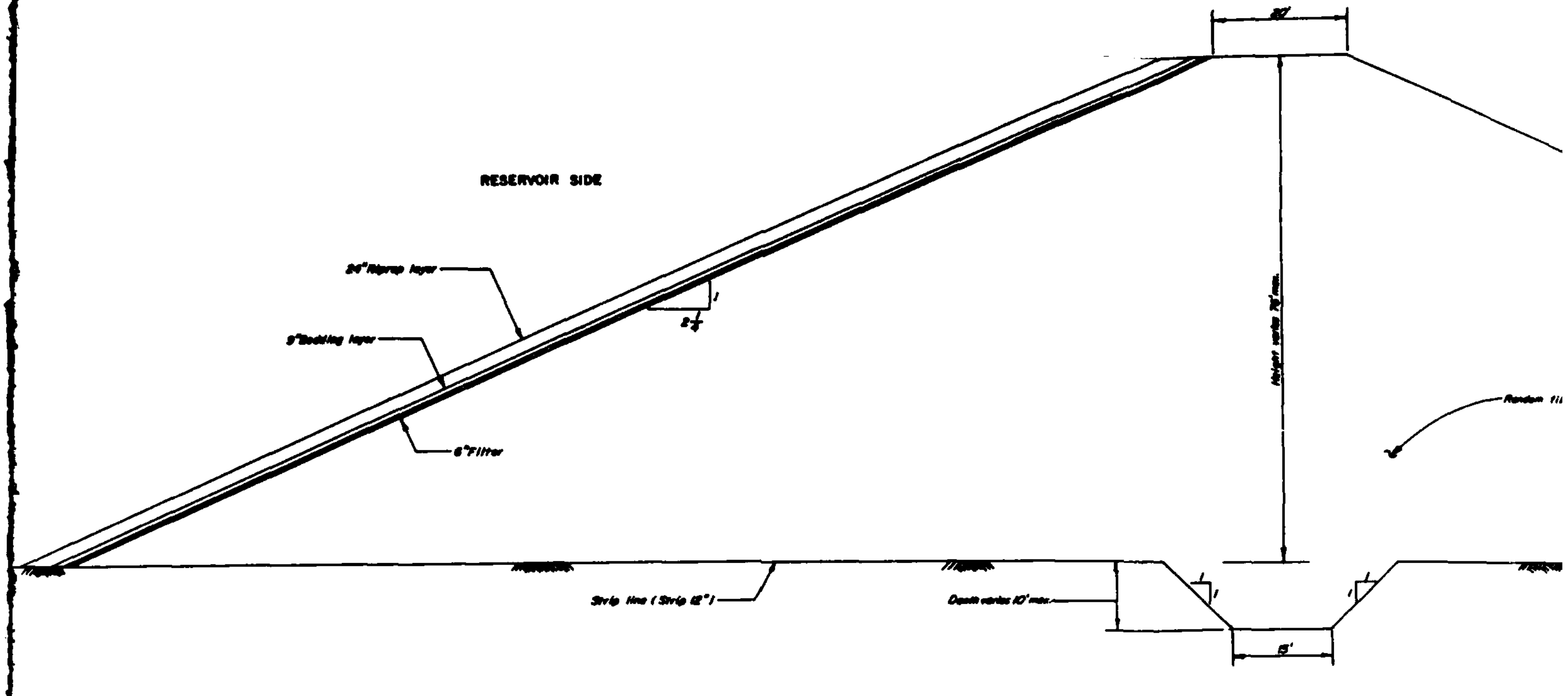
DISTRICT FILE NO.
SHEET

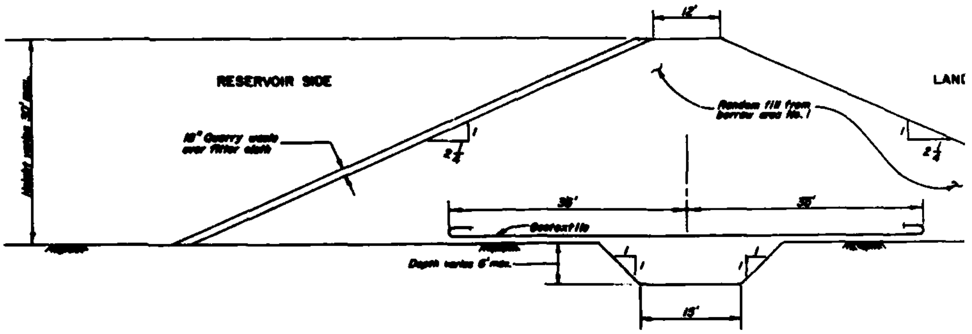
PLATE B-14

2

3

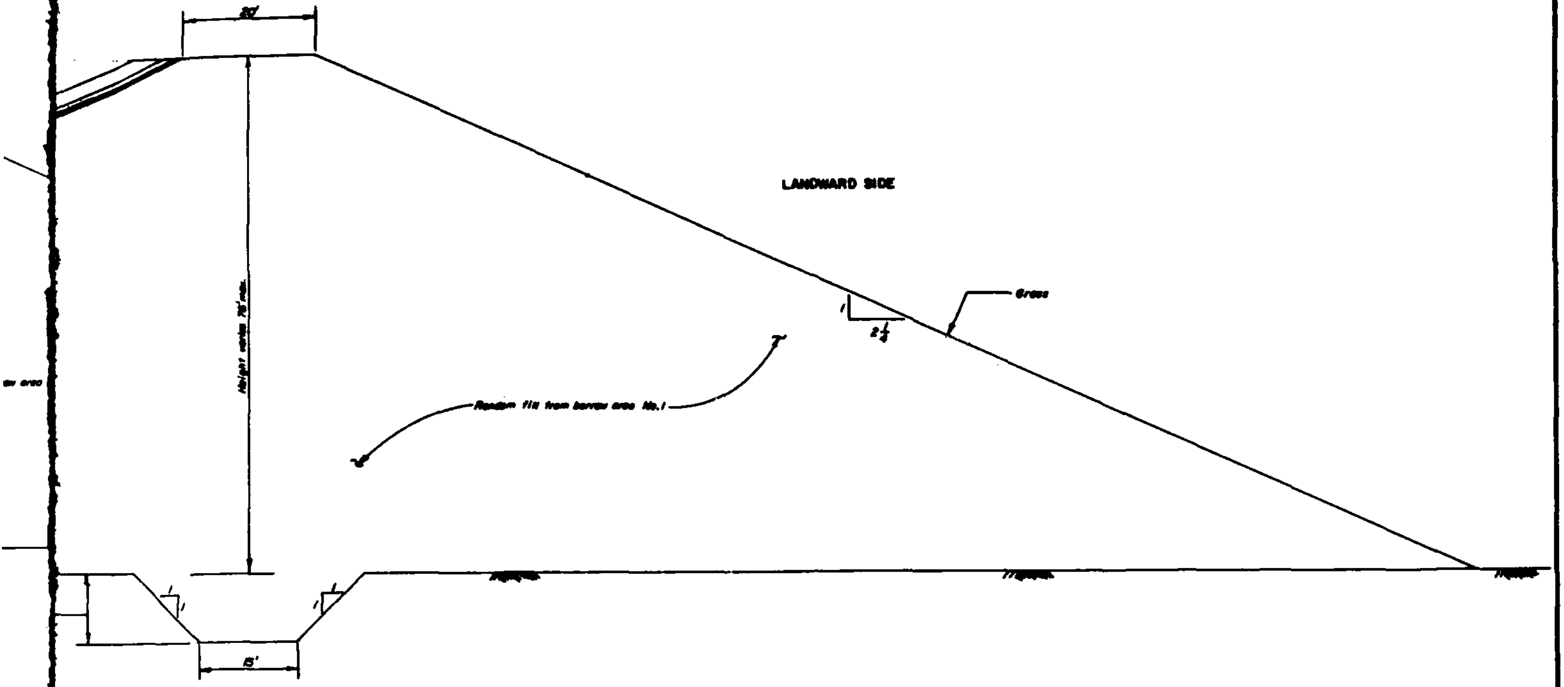


TYPICAL SECTION
AUXILIARY DIKE
SCALE: 1 IN. = 10 FT.

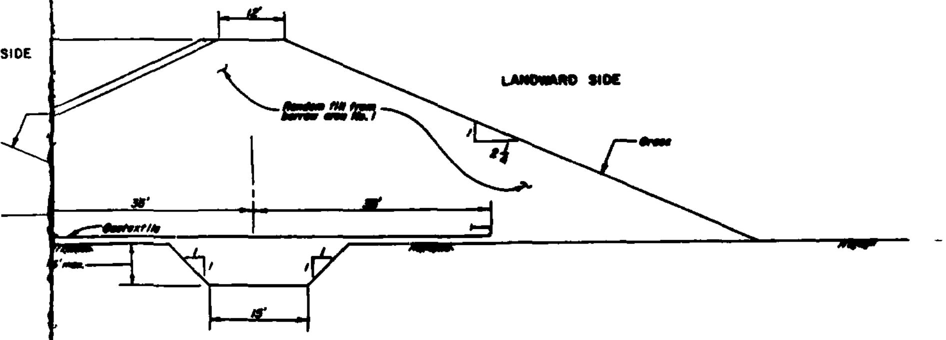


TYPICAL SECTION
DIKE AT ALCOA ALUMINUM PLANT
SCALE: 1 IN. = 10 FT.

VALUE ENGINEERING PAYS



TYPICAL SECTION
AUXILIARY DIKE
SCALE: 1 IN. = 10 FT.



TYPICAL SECTION
DIKE AT ALCOA ALUMINUM PLANT
SCALE: 1 IN. = 10 FT.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY: O. VILPPU

CHECKED BY:

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

TYPICAL SECTION
AUXILIARY DIKE,
DIKE AT ALCOA ALUMINUM PLANT

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____-B-____

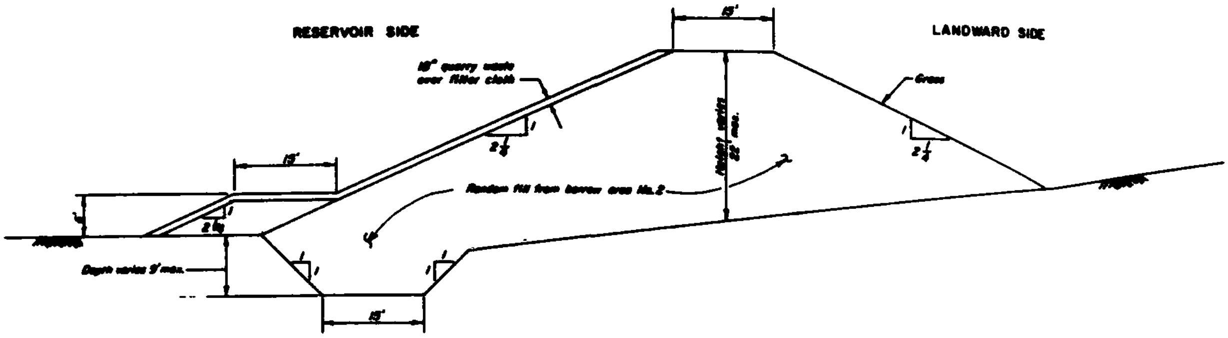
DISTRICT FILE NO.

SHEET

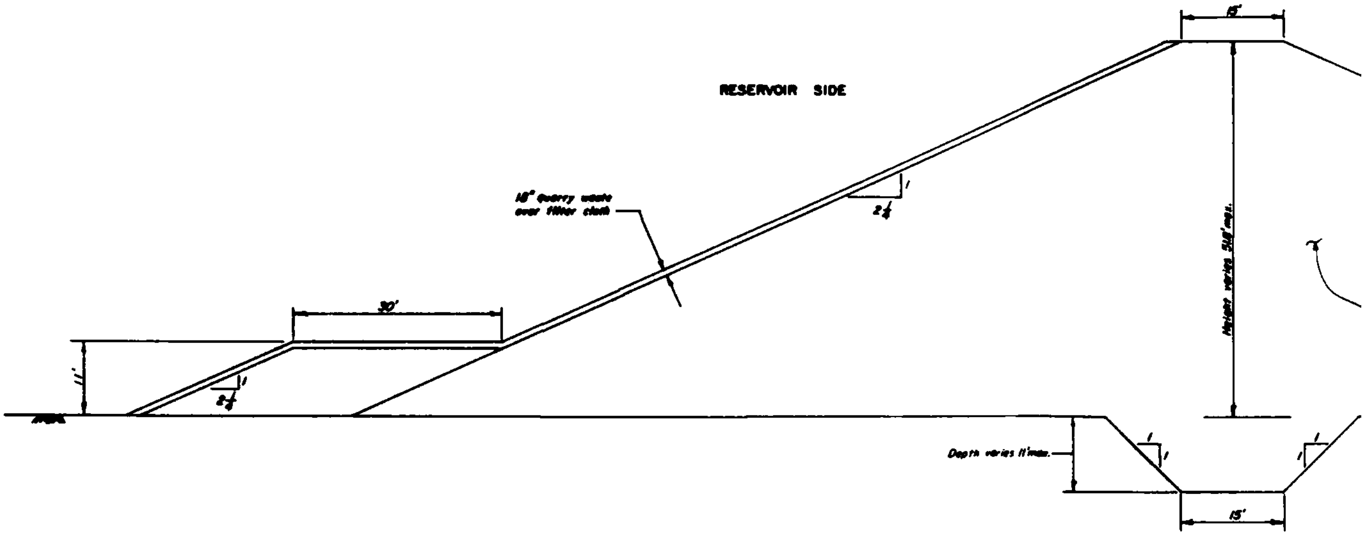
PLATE B-16

2

SAFETY PAYS

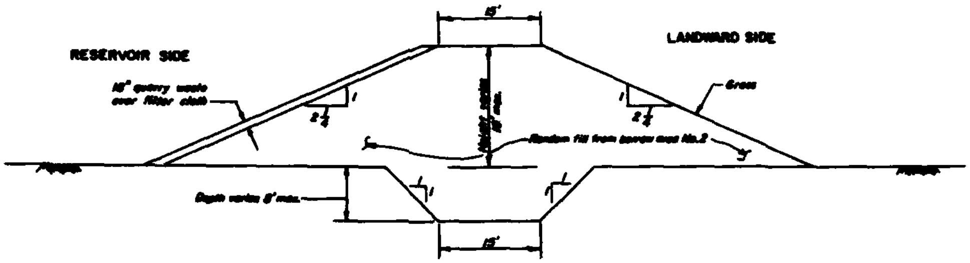


TYPICAL SECTION
DIKE AT CALIFORNIA INSTITUTION FOR WOMEN
STA. 10+00 TO STA. 38+60
SCALE: 1 IN. = 10 FT.

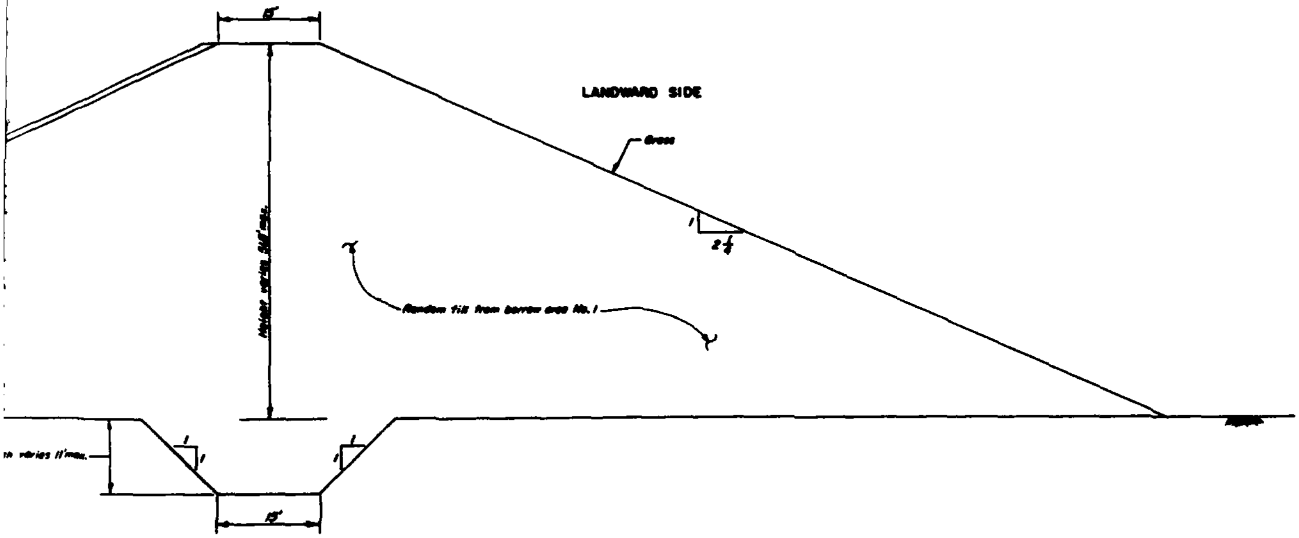


TYPICAL SECTION
DIKE AT CORONA SEWAGE TREATMEN
SCALE: 1 IN. = 10 FT.

ALUE ENGINEERING PAYS



TYPICAL SECTION
DIKE AT CALIFORNIA INSTITUTION FOR WOMEN
STA 43+20 TO STA 72+30
SCALE: 1 IN. = 10 FT.



TYPICAL SECTION
DIKE AT CORONA SEWAGE TREATMENT PLANT
SCALE: 1 IN. = 10 FT.

SCALE: 1 IN. = 10 FT.

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

DRAWN BY
D. VILIPPU

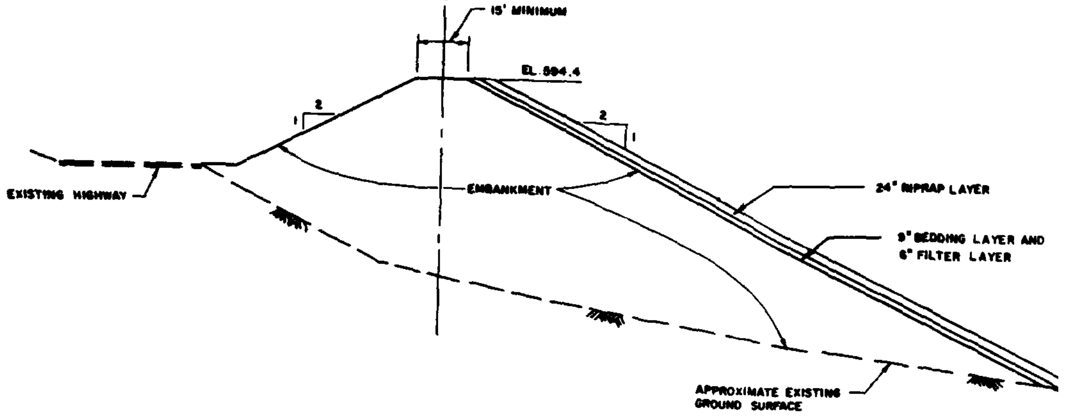
PRADO DAM
TYPICAL SECTION
DIKE AT CORONA SEWAGE TREATMENT PLANT,
DIKE AT CALIFORNIA INSTITUTION FOR WOMEN

SUBMITTED BY
DATE APPROVED
SPEC. NO. DACW09- ___ B- ___
DISTRICT FILE NO.
SHEET

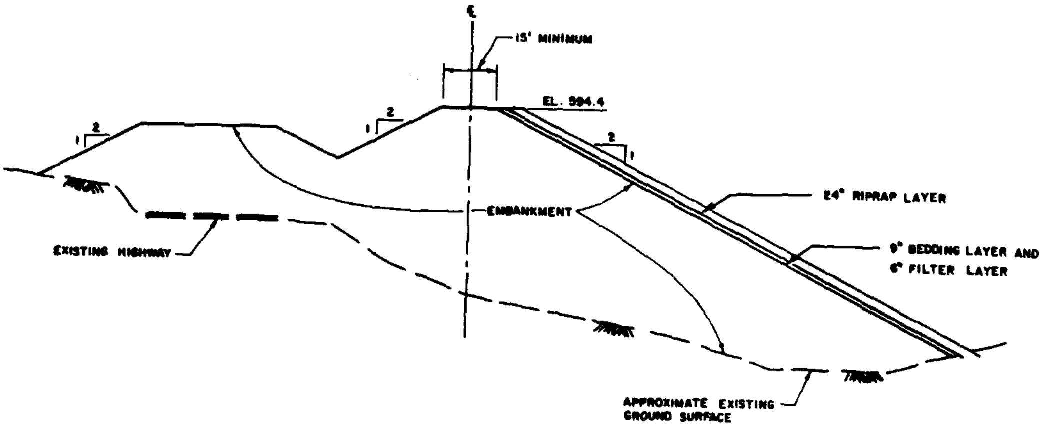
PLATE B-16

SAFETY PAYS

2

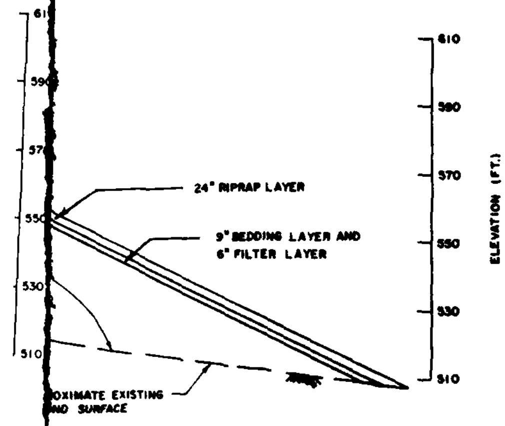


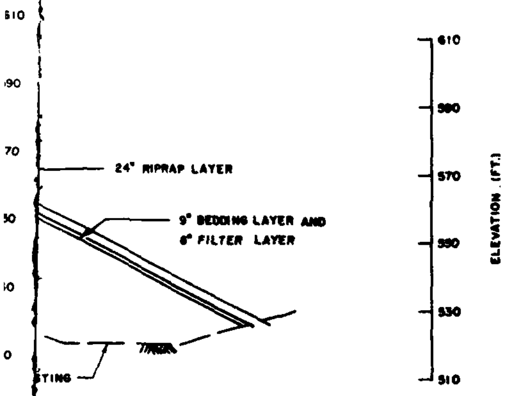
STA. 6+00
SCALE: 1 IN. = 20 FT.



STA. 18+00
SCALE: 1 IN. = 20 FT.

P LUE ENGINEERING PAYS





NOTES:

1. CROSS-SECTIONS ARE DRAWN LOOKING UPSTREAM.

SCALE: 1 IN. = 20 FT.

10 0 10 20 30 40 50

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:
J.T.B.

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

TYPICAL CROSS - SECTIONS
DIKE AT CORONA EXPRESSWAY

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

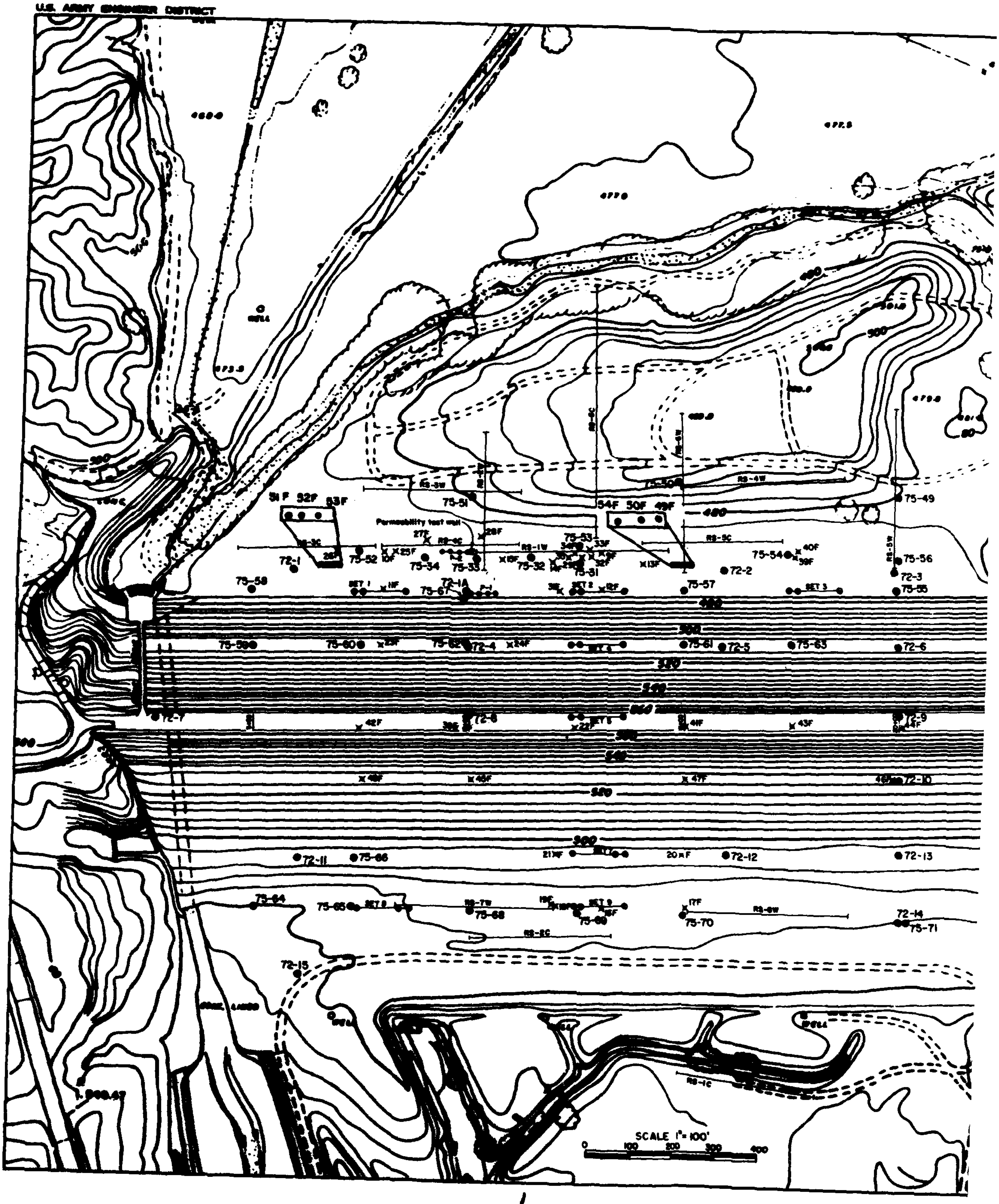
PLATE B-17

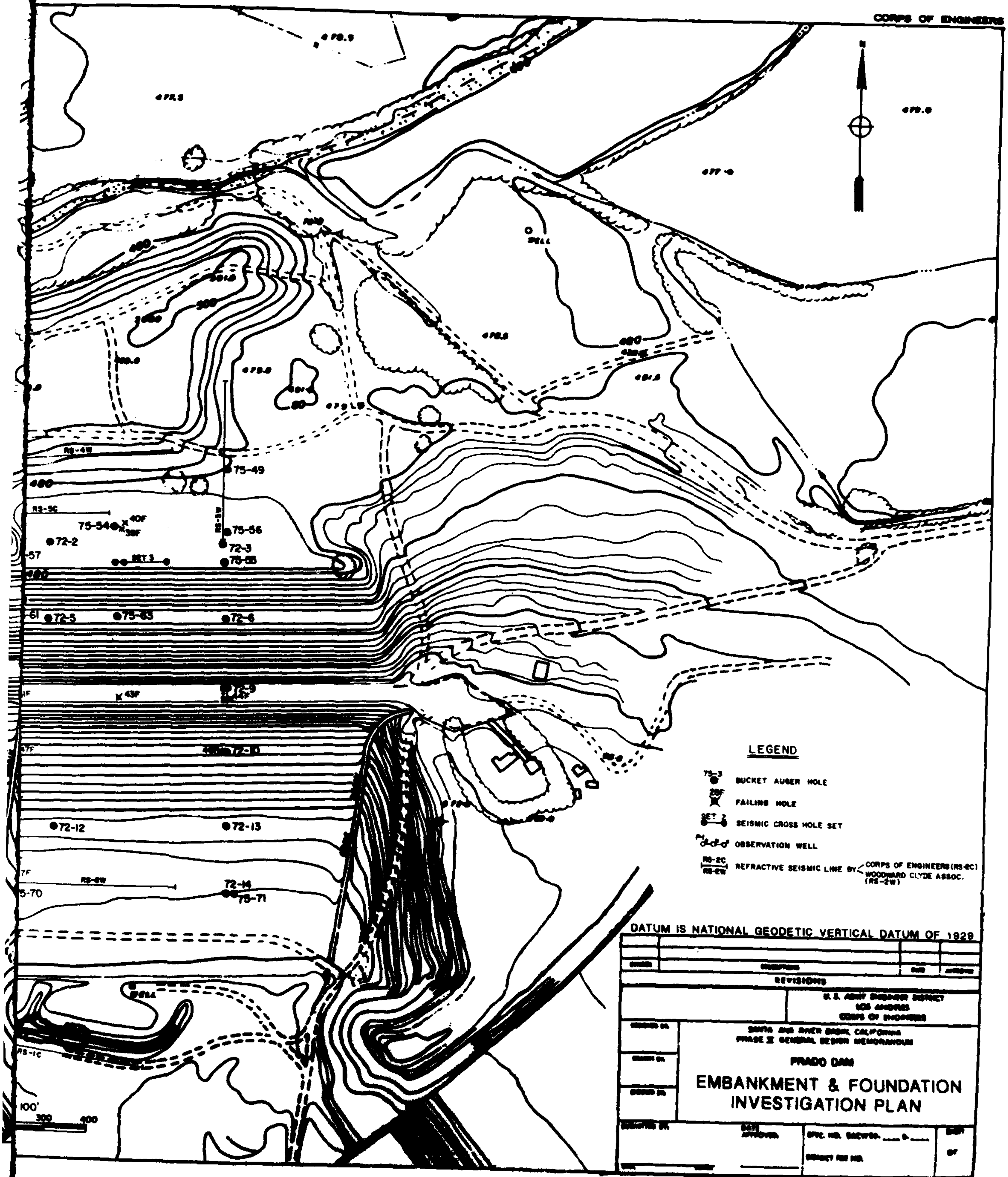
SAFETY PAYS

1

2

U.S. ARMY ENGINEER DISTRICT





LEGEND

75-3 ●	BUCKET AUGER HOLE
28F ☒	FAILING HOLE
SET 2 ●—●	SEISMIC CROSS HOLE SET
OBSERVATION WELL	
RS-2C / RS-2W	REFRACTIVE SEISMIC LINE BY CORPS OF ENGINEERS (RS-2C) / WOODWARD CLYDE ASSOC. (RS-2W)

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

EMBANKMENT & FOUNDATION INVESTIGATION PLAN

PLATE B-18

1

2

PLAN

SCALE 400 0 400 800 1200 FEET

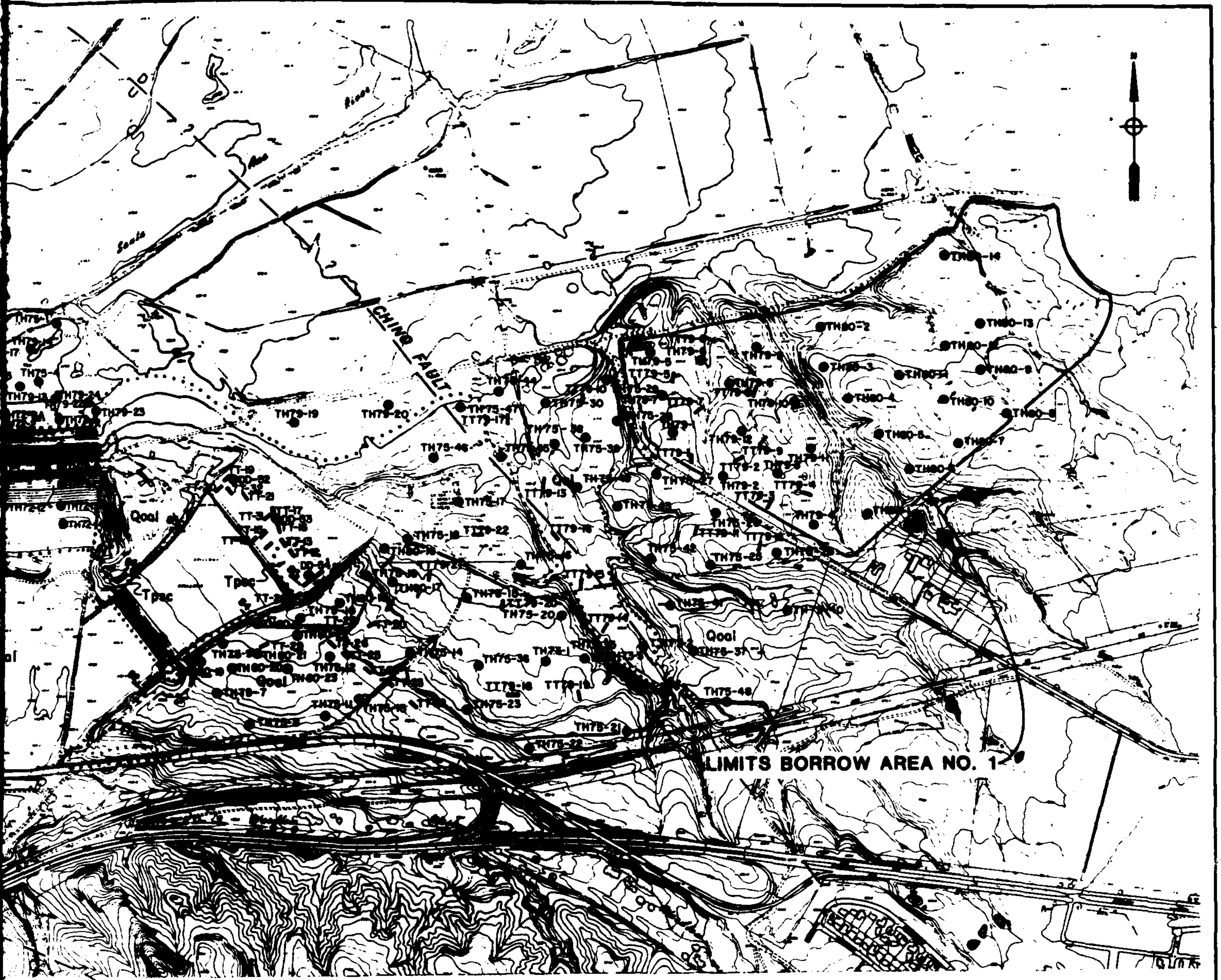
LEGEND

DD-53 ● DIAMOND CORE HOLE LOCA

TH75-1 ● BUCKET AUGUR HOLE LOC Year Drilled

TT79-1 ▬ TEST TRENCH LOCATION Year Drilled

▨ ARCHEOLOGICAL SITE



PLAN

SCALE 400 0 400 800 1200 FEET

LEGEND

DD-53 ●	DIAMOND CORE HOLE LOCATION
TH79-1 ● (Year Drilled)	BUCKET AUGUR HOLE LOCATION
TT79-1 ▬ (Year Drilled)	TEST TRENCH LOCATION
▨	ARCHEOLOGICAL SITE

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

BORROW AREA NO. I
INVESTIGATION PLAN

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-10

1

2

U.S. ARMY ENGINEER DISTRICT

9F (9aF combined)

EL. 475		LL	PI	#-4	#-200	N	γd	Sampler	
	CH	63	36	100	99		75.0	S	
	CH	53	27	100	73		92.5	S	
						12			
	SP-SM	-	NP	98	8		93.6	F	obtained from TH-9
465	SP	-	NP	96	4		96.1	F	
	SM	-	NP	97	16	55		SPT	
						32			
	SP	-	NP	95	3		101.1	F	
	SP-SM	-	NP	92	7			S	
455	SP-SM	-	NP	97	8		98.1	F	γd for TH-9 = 96.1 pcf
	SP-SM	-	NP	99	9	11		S	
	SW-SM	-	NP	97	11	18		S	
	SW	-	NP	84	3			F	gravel disturbed sample
	SW-SM	-	NP	65	5	17 27		SPT	
445	GP-GM	-	NP	50	6	21		S	
435									
	SC	44	26	61	25			P	gravel disturbed sample
	SM	-	NP	94	20	58		SPT	
	SP-SM	-	NP	95	6			P	lost undisturbed sample
425	SM	-	NP	63	23	30		SPT	
	SM	-	NP	68	13	43		S	
415	SP-SM	-	NP	78	6	60 60+		SPT	drilling difficult below el. 415 due to extreme caving. Cobbles were encountered. Hole extended to el. 384 (probable bedrock).

10F

EL. 475		LL	PI	#-4	#-200	N	γd	Sampler	
	CH	63	31	100	98		68.6	S	
						5			
						13			
	SM	-	NP	97	26		106.0	S	
465	SP-SM	-	NP	96	9		92.7	F	
						11			
	SP-SM	-	NP	100	11		94.8	F	
						8			
455	SP	-	NP	92	4		111.4	F	
						7			lost sample from fixed piston @ el. 451 (depth = 24')
						11			
445	SW-SM	-	NP	70	5		105.0	F	
						23			gravel prevented undisturbed sampling
	GW	-	NP	47	4			S	
	SW-SM	-	NP	56	8			S	
	SW-SM	-	NP	55	9		99.0	F	tube badly bent
435						36			
	SM-SC	27	6	79	30			S	
	SW-SM	-	NP	66	10	32		S	
	SW-SM	-	NP	69	10		123.6	P	
						60+			some caving, gravel in SPT
	SP-SM	-	NP	61	8		113.6	P	
425 424						20			

11F

EL. 476 475		LL	PI	#-4	#-200	N	γd	Sampler	
465									
455						30			
	SW	-	NP	94	3		102.5	F	
									sample
						19			
	SW-SM	-	NP	84	6		105.1	F	gray mo
445						26			sample f lost sam two atte
	SM-SC	24	4	59	13	60+		S	
						28			hard to gravel.
435	SC	32	12	64	20	28		SPT	layers o
	SW-SM	-	NP	89	7	60+		S	disturbe
						51			
425	SW-SM	-	NP	76	5	60+ 45		SPT	
416	SW-SM	-	NP	81	5	60+ 60+		SPT	

compacted embankment

foundation

14F (14aF combined)

EL. 475		LL	PI	#-4	#-200	N	γd	Sampler	
	SM	-	NP	99	24		107.3	F	
465	SC SM	34	17 NP	99 96	38 30		88.3 106.0	F	sample divided
	SM	-	NP	100	22		97.0	S	(14A)
									lost sample (14)
	SW-SM	-	NP	94	7		112.7	S	(14A)
									lost sample (14)
455	GW	-	NP	40	4	10	90.2	S	(14A)
	SM	-	NP	75	17		100.5	S	(14A)
						30			lost sample (14) due to gravel.
	SP-SM	-	NP	91	6		106.2	S	(14A)
						3			
	SM	35	6	74	34		90.2	S	
445									lost sample from push tube
	SM	-	NP	100	23			S	grey
						30			
	SW-SM	-	NP	89	9			S	
						26			
	SW-SM	-	NP	87	10			S	
436						23			cobbles encountered

15F

EL. 475		LL	PI	#-4	#-200	N	γd	Sampler	
	Ch	62	33	100	100		85.6	P	gray
						5			
	CH SM	62 -	34 NP	100 99	98 33		67.8 101.8	P	sample divided
465						6			
	SP-SM	-	NP	94	10		95.8	F	gray
						10			
	SP	-	NP	90	2		103.1	F	
455						7			
	SP-SM	-	NP	96	7		99.0	F	
						27			
	SW-SM	-	NP	92	5		119.3	F	
						28			
445	SW-SM	-	NP	75	9		114.2	F	tube bent
						51			
		-	NP	99	4		105.6	F	
						48			
	SW-SM	-	NP	85	8		110.4	F	tube bent
						60+			grey
435	SW-SM	-	NP	94	7		106.4	F	grey
						36			
	SC	36	17	65	14			F	lost sample
						60			
	SM	—	NP	84	16			S	grey, dense
425	SW-SM	-	NP	73	9	38		S	
	SM	—	NP	96	17	60+		S	thin clay layers
	SP-SM	-	NP	87	9	38		S	←firm brown clay lens
416	SW-SM	-	NP	81	7	60		S	lost sample (P) @ el. 416-414

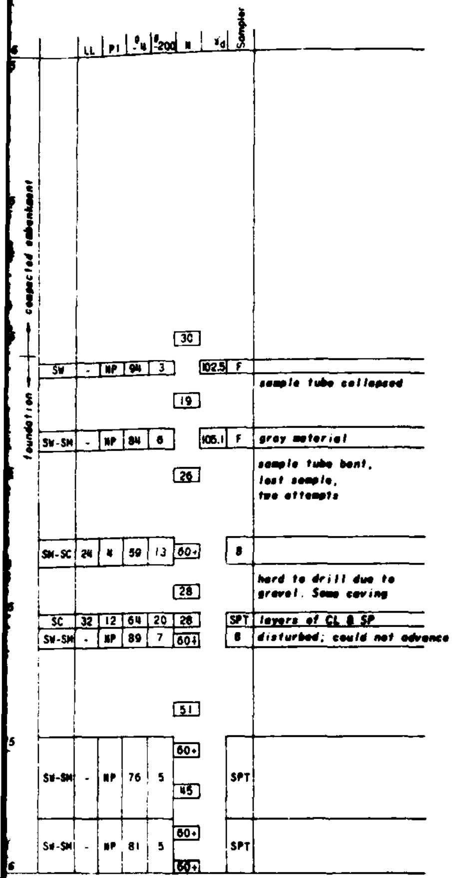
16F

EL. 486 485		LL	PI	#-4	#-200	N	γd	Sampler	
475	SM	-	NP	95	24		110.8	P	
						36			
465	SM	-	NP	95	22		116.8	P	
						37			
455						48			
	SM	-	NP	84	24		117.9	F	
						60			tan, fine
	SW-SM	-	NP	79	7		106.6	F	brown
						50			brown
	SP	-	NP	82	3		104.0	F	
445	SM	-	NP	88	14	48		S	grey & ta like D.G
	SP-SM	-	NP	69	11	52		S	some clay
	SM	-	NP	90	15	60+		S	gray
435	SW-SM	-	NP	80	12	60+		S	
	SW-SM	-	NP	78	12	60+		S	
425									
423	SM	-	NP	66	14	57		SPT	

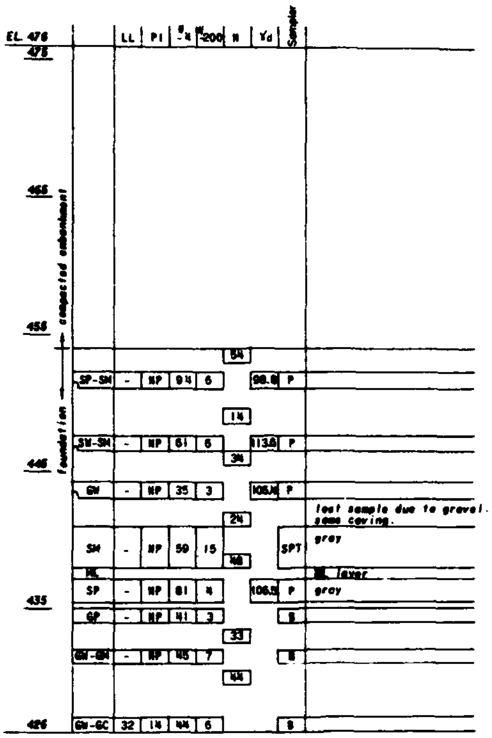
compacted embankment

foundation

11F



12F



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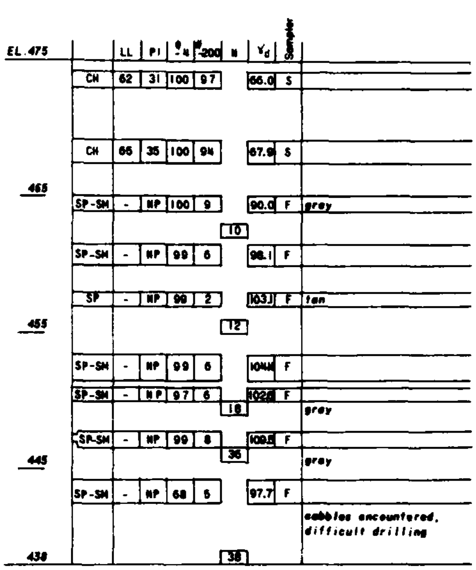
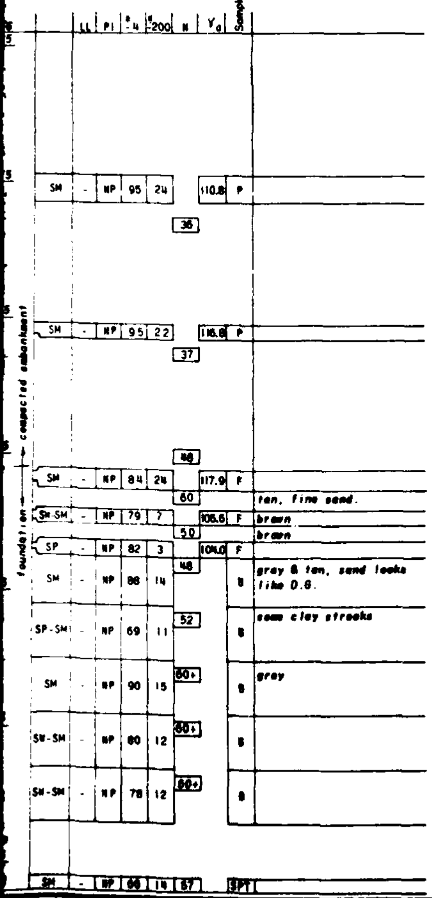


16F



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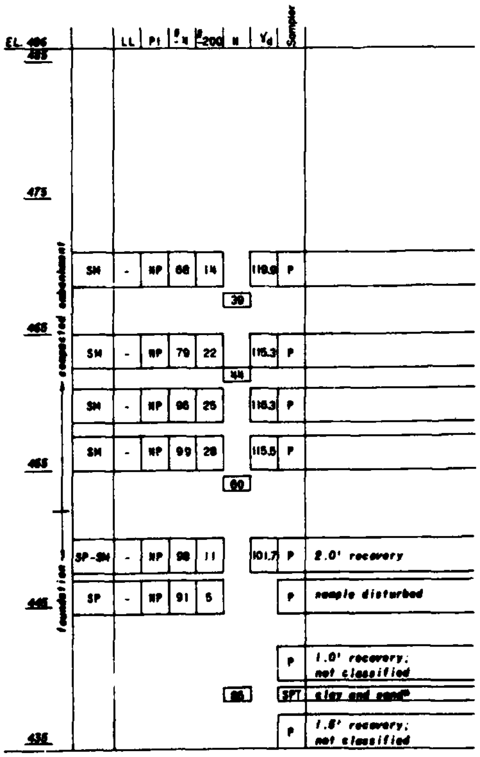


VERTICAL SCALE: 1 INCH = 5 FEET

SCALE 0 5 10 15 FEET

LEGEND

12F	NUMBER OF 4-3/4-INCH DIAMETER, FAILING RIG, TEST HOLE
LL	LIQUID LIMIT
PI	PLASTICITY INDEX
-#4	PERCENT BY WEIGHT PASSING #4 SIEVE
-#200	PERCENT BY WEIGHT PASSING #200 SIEVE
N	NUMBER OF BLOWS PER FOOT FOR SPT
γd	DRY DENSITY (PCF)
SP	SOIL CLASSIFICATION (USCS)
F	FIXED PISTON SAMPLER
P	PITCHER SAMPLER
S	PUSH TUBE
B	BAG SAMPLE
SPT	STANDARD PENETROMETER
NP	NON PLASTIC (USUALLY FIELD DETERMINATION)
*	VISUAL CLASSIFICATION
**	GRAVEL IN SHOE OF PENETROMETER

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

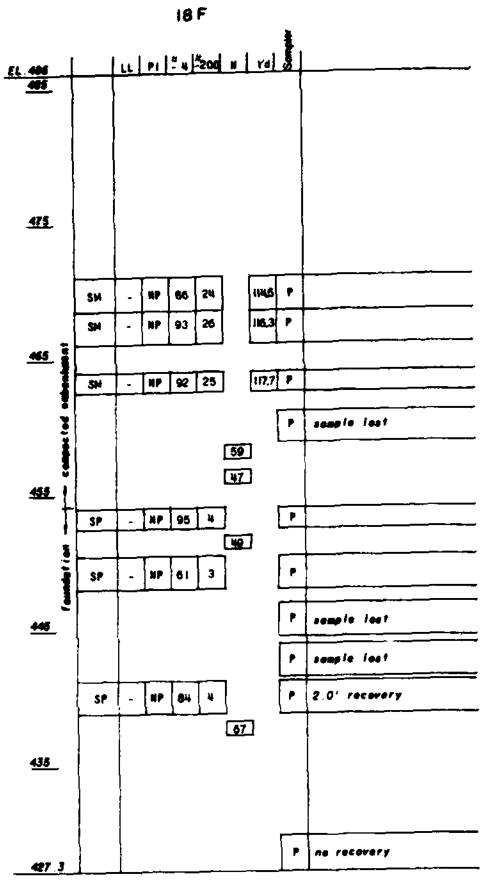
SOIL LOGS
9F THRU 17F

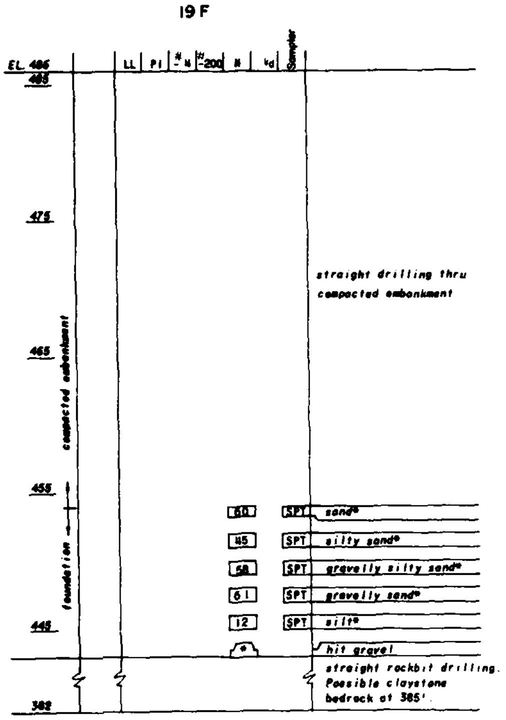
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

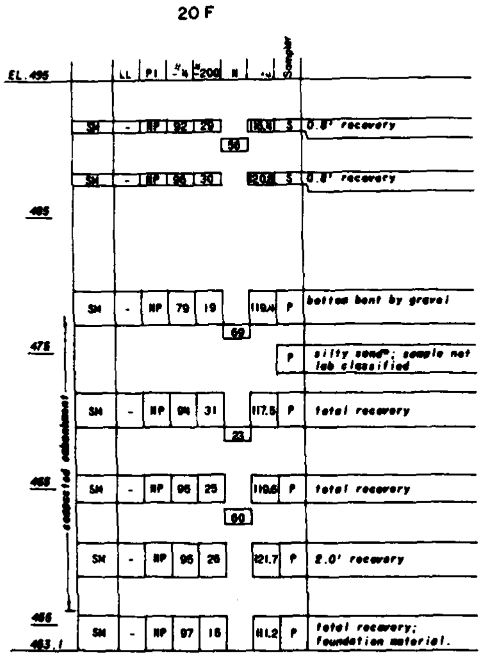
PLATE B-20

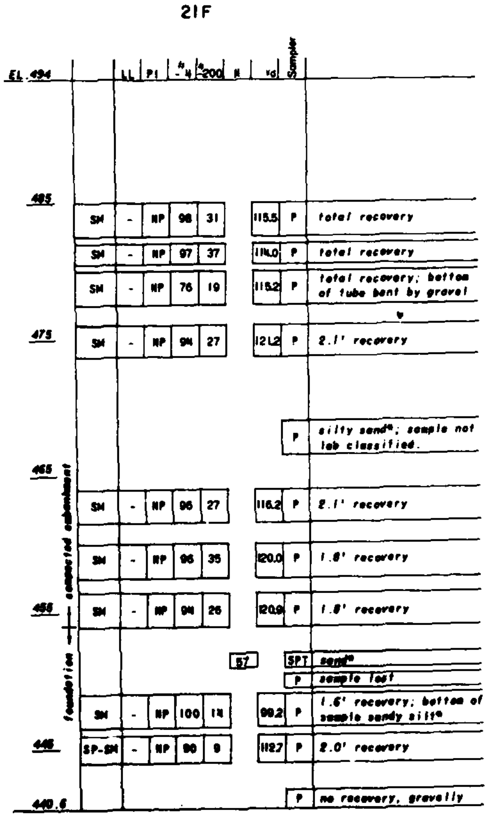
2

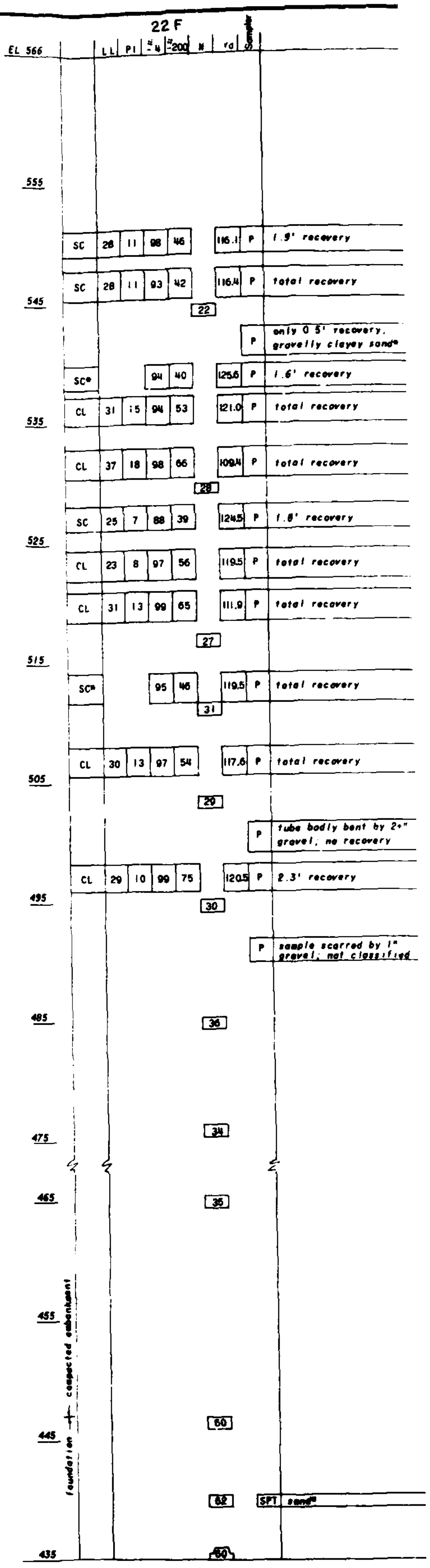
U.S. ARMY ENGINEER DISTRICT











CORPS OF ENGINEERS

22 F

	LL	PI	-#4	-#200	N	γd	Sampler	
SC	28	11	98	46		116.1	P	1.9' recovery
SC	28	11	93	42		116.4	P	total recovery
					22			
							P	only 0.5' recovery, gravelly clayey sand*
SC*			94	40		125.6	P	1.6' recovery
CL	31	15	94	53		121.0	P	total recovery
CL	37	18	98	66		109.4	P	total recovery
					28			
SC	25	7	88	39		124.5	P	1.8' recovery
CL	23	8	97	56		119.5	P	total recovery
CL	31	13	99	65		111.9	P	total recovery
					27			
SC*			95	46		119.5	P	total recovery
					31			
CL	30	13	97	54		117.6	P	total recovery
					29			
							P	tube badly bent by 2+" gravel; no recovery
CL	29	10	99	75		120.5	P	2.3' recovery
					30			
							P	sample scarred by 1" gravel; not classified
					36			
					34			
					35			
					60			
					62		SPT	sand*
					60			

23 F

foundation — compacted embankment

EL.		LL	PI	-#4	-#200	N	γd	Sampler	
510									
505									
	SM	-	NP	95	34		110.8	P	total recovery
	SM	-	NP	94	36		116.8	P	total recovery
495									
								P	no recovery
								P	0.3' recovery not lab. class., silty sand*
	SC	28	12	87	38		122.9	P	total recovery
485	CL	30	14	93	54		115.2	P	total recovery
	SC	29	13	90	42		119.2	P	0.8' recovery
	SC*			96	25		126.7	P	1.7' recovery
	CL*			81	52		112.0	P	total recovery
475									
	SC	27	11	92	21		128.2	P	total recovery
								P	sample disturbed by 2" gravel gravelly clayey sand*
465	CL*			93	54		125.4	P	2.0' recovery
								P	1.0' recovery, not lab. class., clayey sand*
								P	2.1' recovery, not lab. class., clayey sand*
								P	0.8' recovery, not lab. class., gravelly clayey sand*
455									
	SP	-	NP	98	4		105.8	P	1.0' recovery
								P	0.4' recovery, not lab. class., gravelly sand*
	SM	-	NP	90	21		106.4	P	1.7' recovery
445									strong aquifer encountered at elevation 445; experienced severe caving.
441.2									

24 F

foundation — compacted embankment

EL.		LL	PI	-#4	-#200	N	γd	Sampler	
510									
505									
	SM	-	NP	90	30		104.0	P	2.0' recovery
	SM	-	NP	83	27		123.2	P	1.0' recovery
495	SM	-	NP	84	27		117.4	P	1.6' recovery, bottom badly bent, probably disturbed
								P	gravelly silty sand*
								P	gravelly clayey sand*
485	SC	25	9	90	32		122.8	P	1.7' recovery
	SC	26	10	87	23		123.8	P	1.8' recovery
	SC*			67	16		123.8	P	0.8' recovery
475	CL*			92	56		121.7	P	1.3' recovery
	CL	30	13	91	52		121.0	P	1.9' recovery
	SC	30	13	88	45		119.0	P	2.1' recovery
465									
								P	clayey sand*
	SM	24	4	70	23		127.4	P	0.9' recovery
	ML	22	NP	96	62		116.0	P	1.9' recovery
								P	gravelly clayey sand* to 457.3 then silty sand*
455	SP	-	NP	44	4		109.4	P	1.5' recovery
	SP-SM	-	NP	93	7		114.8	P	1.7' recovery
	SP-SM	-	NP	100	8		104.9	P	1.7' recovery
445									coarse gravel and cobbles
									Installed piezometer; bottom elevation 440.8'. Backfilled with clean sand to elevation 449.
440									

25 F

EL.		LL	PI	-#4	-#200	N	γd	Sampler	
475									
465									straight drilling to elevation 463.3
455									
								F	no recovery
								F	no recovery
								F	no recovery
	SW	-	NP	77	4		116.3	P	1.7' recovery
445	GW	-	NP	31	1		110.6	P	1.5' recovery
								F	no recovery
440.7									

NOTES

1. SEE PLATE 20 FOR LEGEND.

VERTICAL SCALE: 1 INCH = 5 FEET

SCALE 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

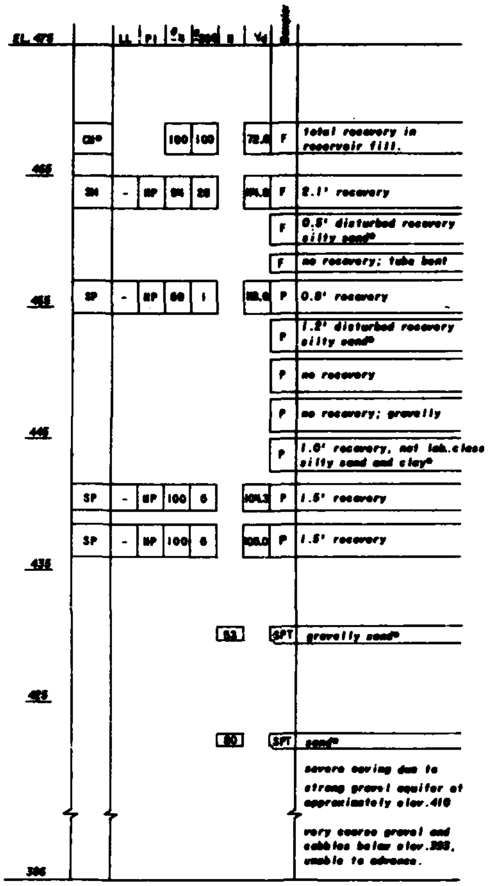
PRADO DAM

SOIL LOGS
18F THRU 25F

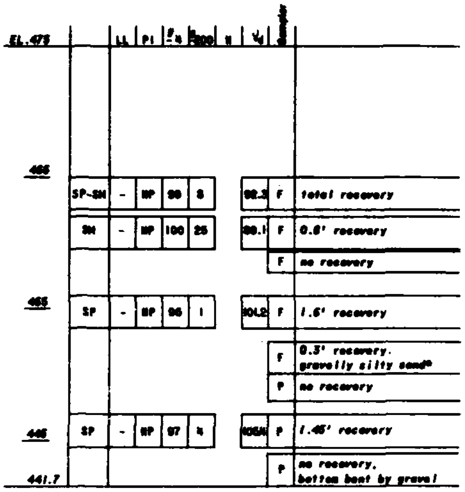
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09- ____ B- ____
DISTRICT FILE NO.
SHEET

U.S. ARMY ENGINEER DISTRICT

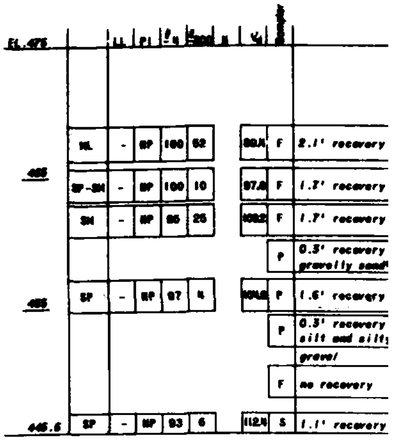
26 F



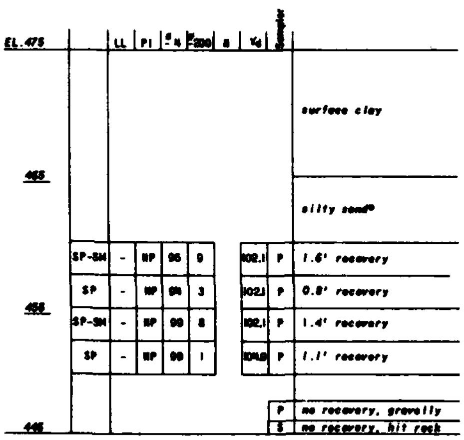
27 F



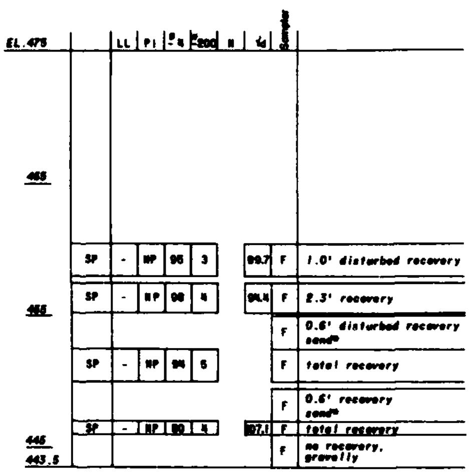
28 F



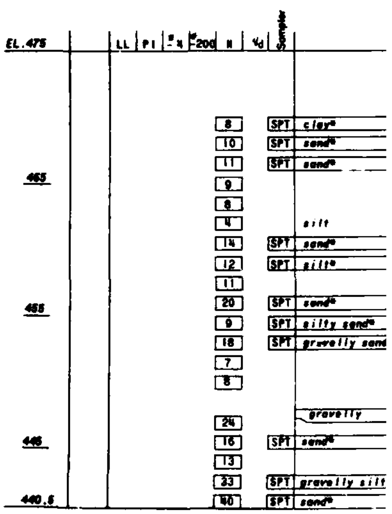
32 F



34 F



39 F



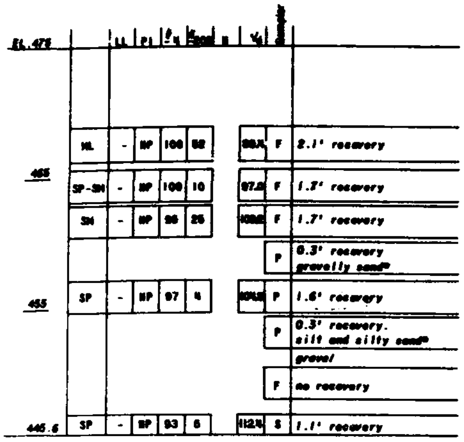
33 F

No samples were recovered in hole 33F. Cobble advanced ahead of bit. Hole abandoned.

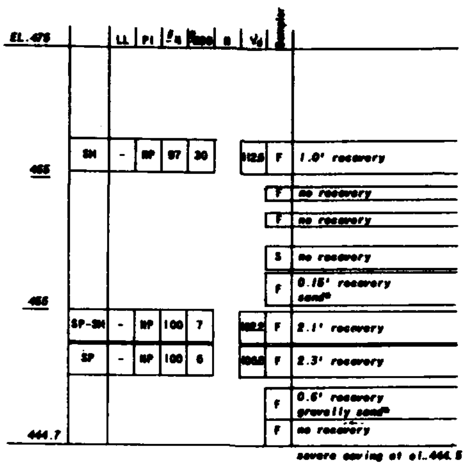
35 F

After two unsuccessful attempts with fixed piston sampler hit boulder or too stone at el.456.
Hole abandoned.

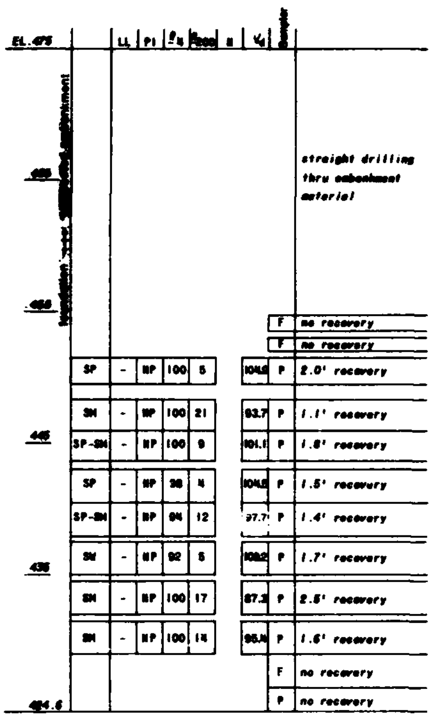
28 F



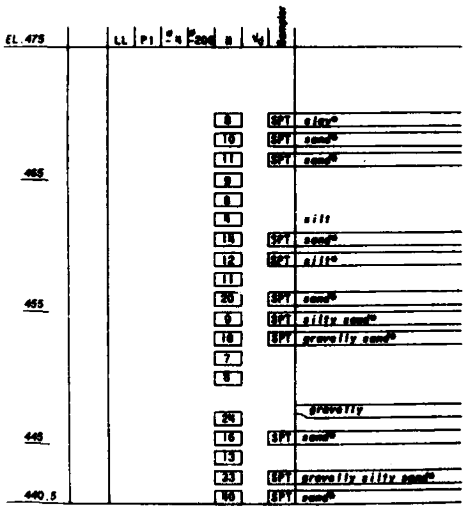
29 F



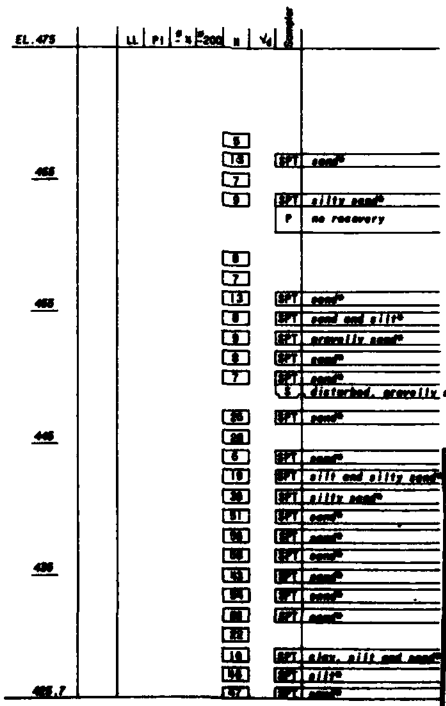
31F



39 F



40 F



NOTES

1. SEE PLATE 20 FOR LEGEND.
2. HOLE 36F WAS NOT LOGGED AND NO SAMPLES WERE TAKEN OR PENETRATION TESTS PERFORMED.
3. HOLE 37F WAS DRILLED FOR THE SOLE PURPOSE OF OBTAINING ONE UNDISTURBED PITCHER SAMPLE OF THE CORE ZONE FOR ADDITIONAL DYNAMIC ANALYSIS AND WAS NOT LOGGED.
4. LOG OF HOLE 38F IS PRESENTED ON PLATE 23.

VERTICAL SCALE: 1 INCH = 5 FEET

SCALE 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY.

DRAWN BY.

CHECKED BY.

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
28F THRU 29F
31F THRU 36F, 39F, 40F

SUBMITTED BY.

DATE APPROVED.

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

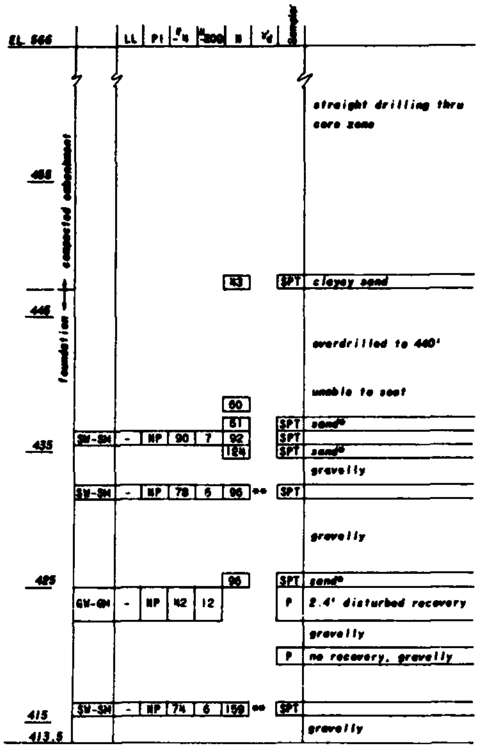
SHEET

1

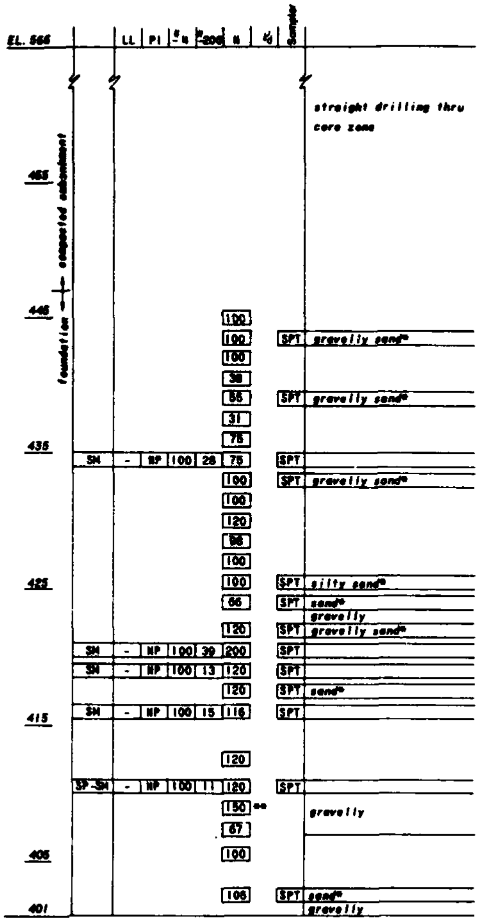
2

U.S. ARMY ENGINEER DISTRICT

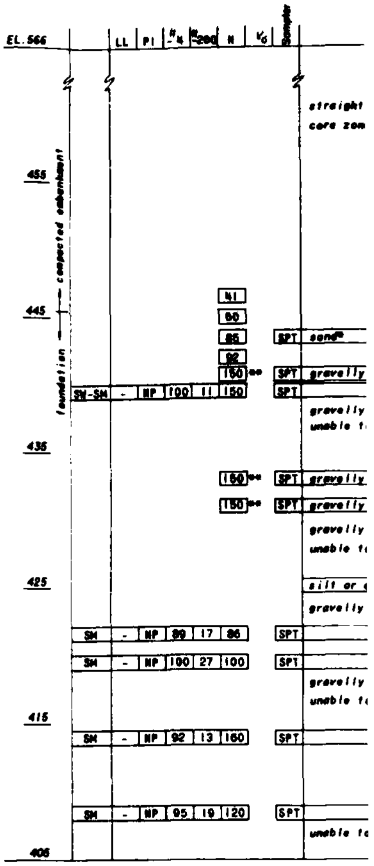
38 F



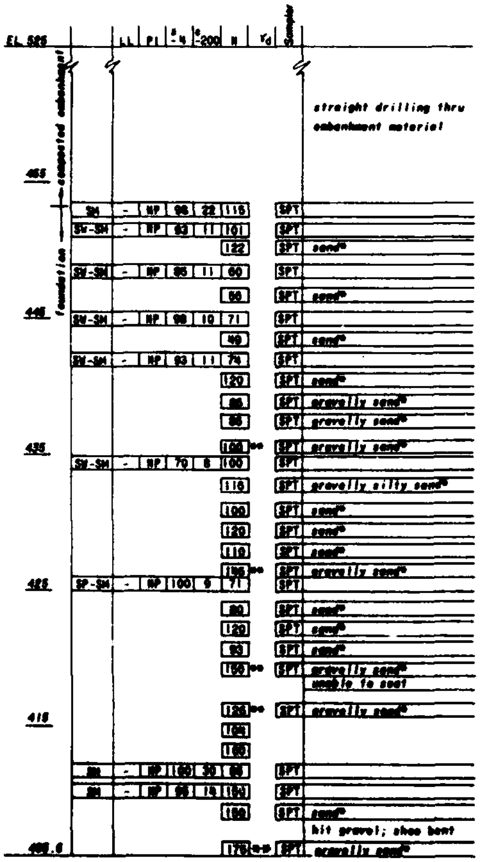
41F



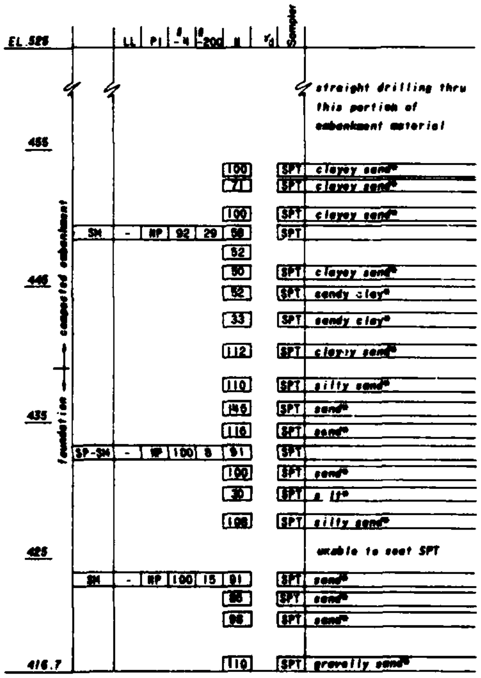
42 F



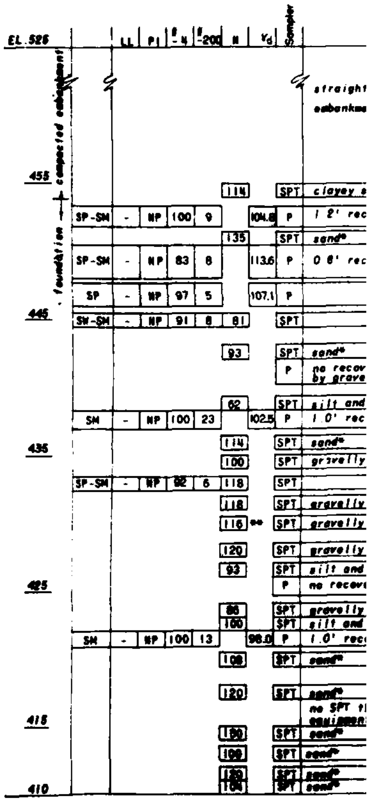
45 F



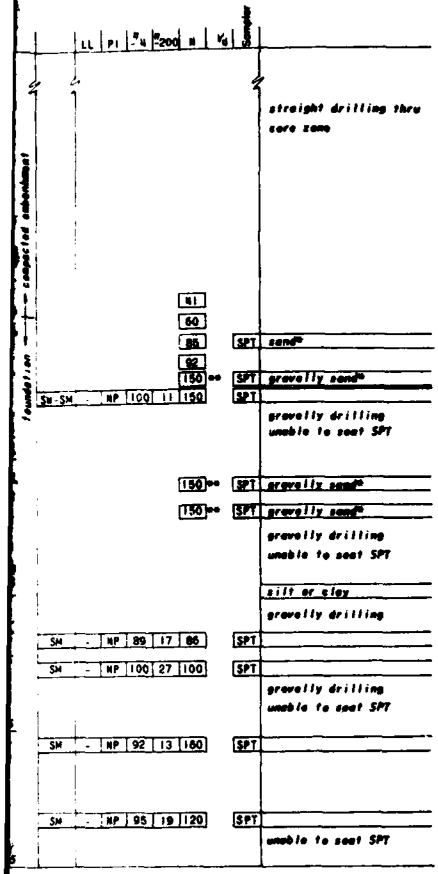
46 F



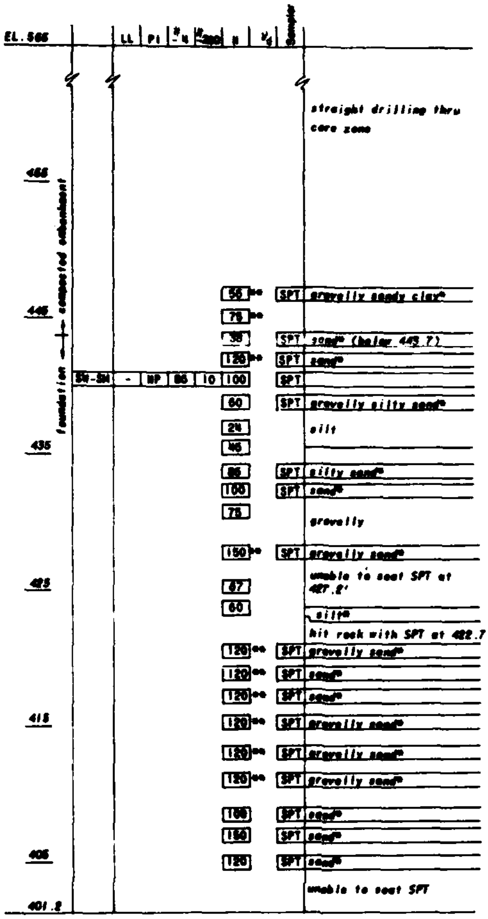
47 F



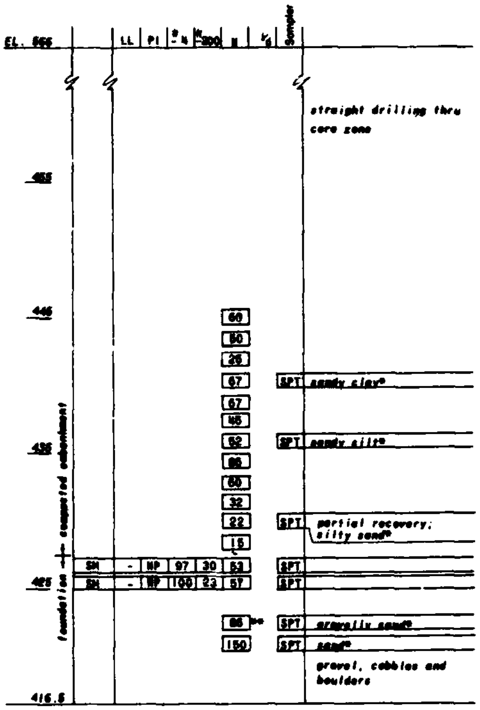
42 F



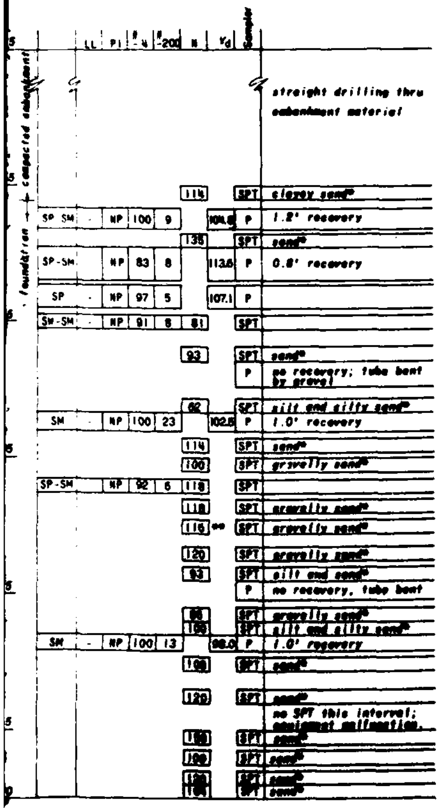
43 F



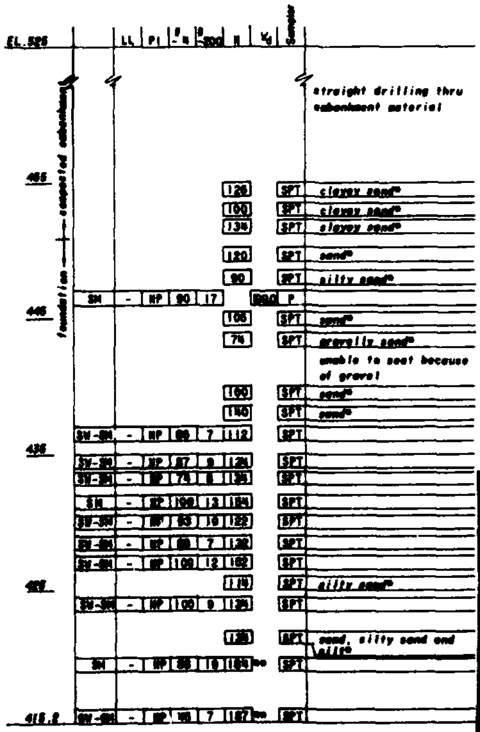
44 F



47 F



48 F



NOTES

1. SEE PLATE 20 FOR LEGEND
2. HOLES 38F AND 41F THRU 44F WERE DRILLED ON THE CREST OF THE DAM ON THE DOWNSTREAM SIDE OF THE SHEET-PILE CUTOFF.
3. AS A GENERAL RULE THE SPT WAS SEATED SIX INCHES THEN DRIVEN ONE FOOT OR 60 BLOWS, WHICH EVER CAME FIRST. N VALUES GREATER THAN 60 WERE EXTRAPOLATED FROM THE NUMBER OF BLOWS NEEDED TO ADVANCE A FRACTION OF THE FOOT (60 BLOWS FOR 0.5' = 120 BLOWS).

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
38F, 41F THRU 48F

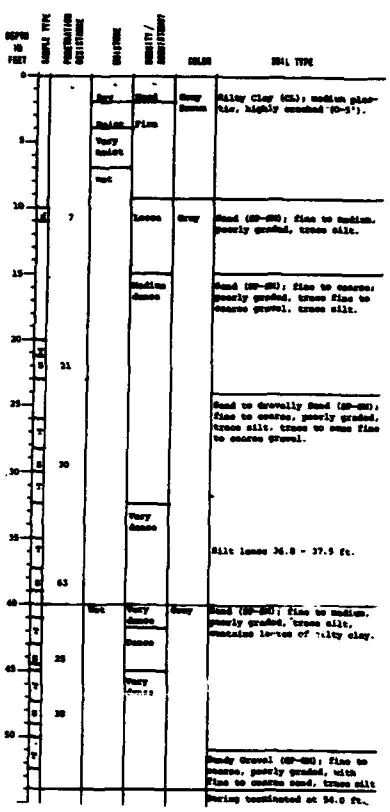
SUBMITTED BY:
DATE APPROVED
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET
TITLE ____ DATE

PLATE B-20

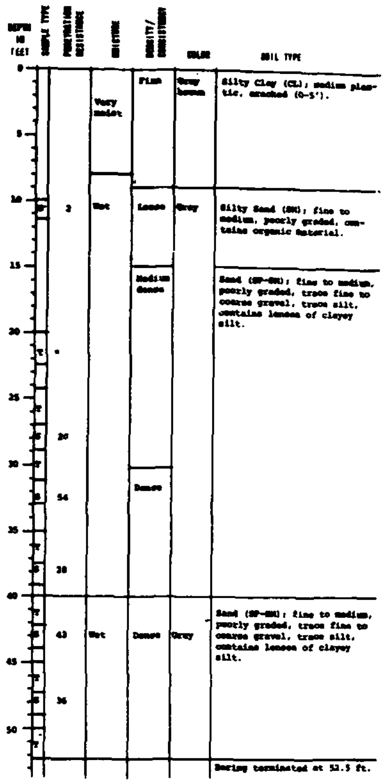
2

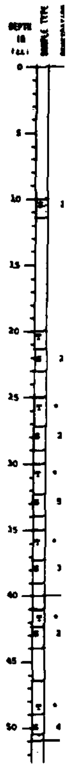
VALUE ENGINEERI

49 F

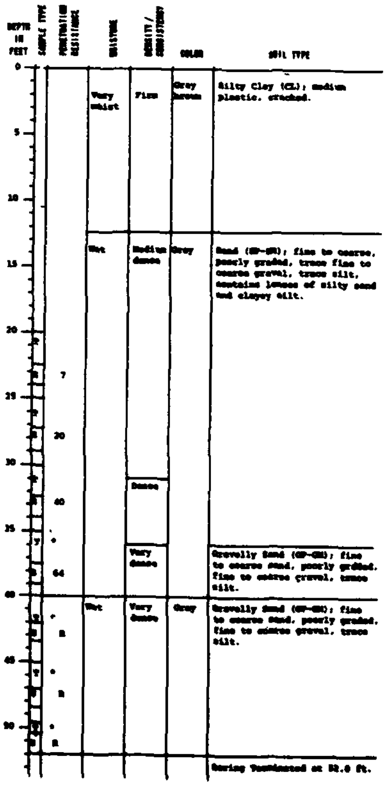


50 F

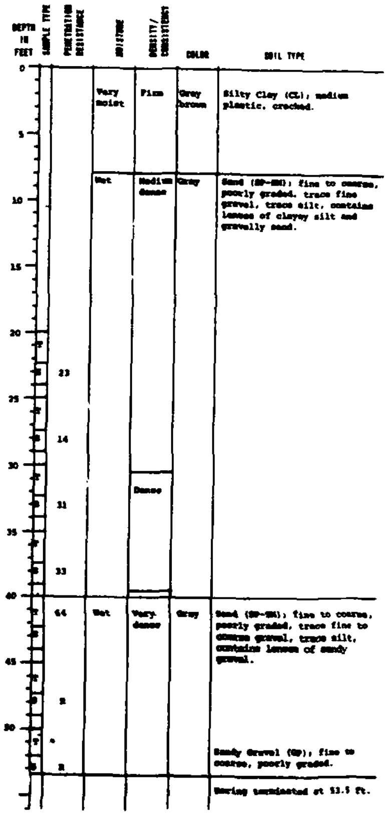




53 F

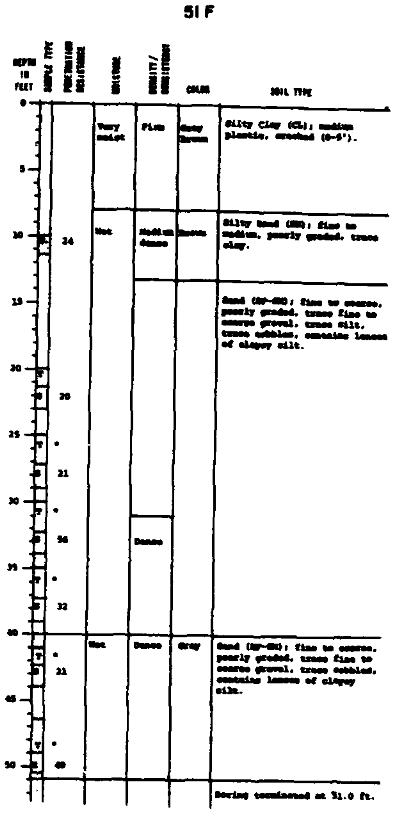


54 F



SAFETY PA

LUE ENGINEERING PAYS



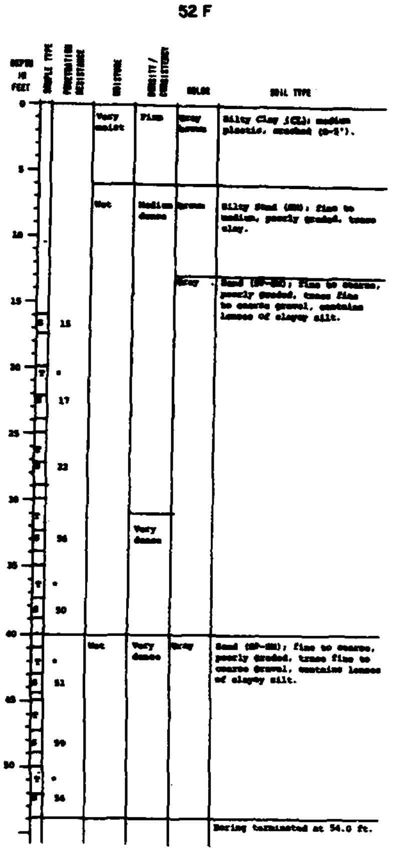
Silty Clay (CL); medium plastic, crushed (0-5').

Silty Sand (SM); fine to medium, poorly graded, trace clay.

Sand (SP-SM); fine to coarse, poorly graded, trace fine to coarse gravel, trace silt, trace cobbles, contains lenses of clayey silt.

Sand (SP-SM); fine to coarse, poorly graded, trace fine to coarse gravel, trace cobbles, contains lenses of clayey silt.

Boring terminated at 51.0 ft.



Silty Clay (CL); medium plastic, crushed (0-5').

Silty Sand (SM); fine to medium, poorly graded, trace clay.

Sand (SP-SM); fine to coarse, poorly graded, trace fine to coarse gravel, contains lenses of clayey silt.

Sand (SP-SM); fine to coarse, poorly graded, trace fine to coarse gravel, contains lenses of clayey silt.

Boring terminated at 54.0 ft.

LEGEND

S	STANDARD SPLIT SPOON SAMPLE (ASTM D1586)
T	THIN WALL TUBE SAMPLE (ASTM D1587)
*	NO RECOVERY
R =	REFUSAL

NOTES:

1. HOLES 49F TO 52F WERE DRILLED WITH A CME-55 DRILL RIG. HOLES 53F AND 54F WERE DRILLED WITH A FAILING 1500 DRILL RIG.
2. HOLES WERE DRILLED DURING 18 OCT. 83 TO 3 DEC. 83.
3. ELEVATION OF TOP OF HOLES IS 475' ±.
4. SEE PLATE 10 FOR LOCATION OF HOLES.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL
DESCRIPTIONS
DATE
APPROVAL
REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE I GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
49F THRU 54F

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-64

SAFETY PAYS

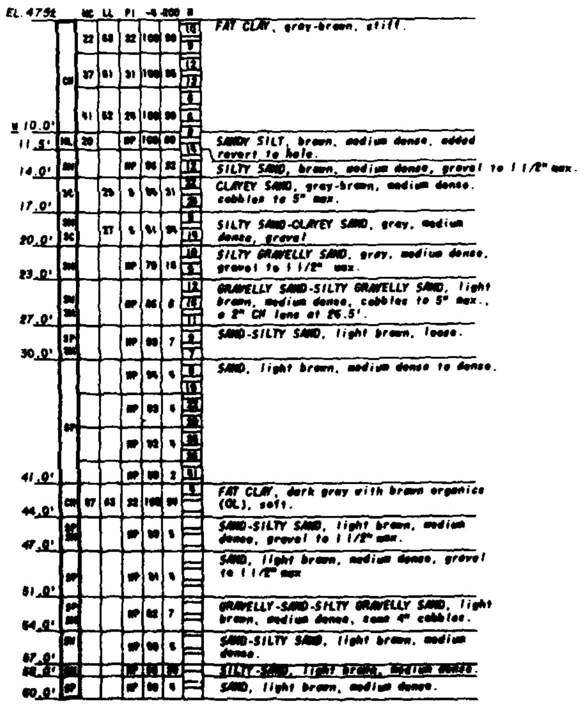
2

U.S. ARMY ENGINEER DISTRICT

SUMMARY OF BORINGS

BORING NUMBER	STATION NUMBER	OFFSET FROM ℄ (FEET)	SURFACE ELEV. (FEET)	TYPE OF BORING
72- 1	6+00	365 US	475	SPT, 16" DIA
72- 2	15+00	365 US	475	↓
72- 3	20+00	365 US	475	↓
72- 4	10+00	175 US	510	↓
72- 5	15+00	175 US	510	↓
72- 6	20+00	175 US	510	↓
72- 7	2+65	10 US	566	↓
72- 8	10+00	10 US	566	↓
72- 9	20+00	10 US	566	↓
72-10	20+00	135 DS	525	↓
72-11	6+00	325 DS	485	↓
72-12	15+00	325 DS	485	↓
72 13	20+00	325 DS	485	↓
72-14	20+00	470 DS	484	↓
72-15	6+00	560 DS	480	↓
75- 1	20+25	1045 US	485	↓
75- 2	7+40	535 US	475	↓
75- 3	14+05	800 US	487	↓
75- 4	17+60	625 US	486	↓
75- 7	NA	NA	578	BORROW, 16" DIA
75- 8	↓	↓	568	↓
75- 9	↓	↓	561	↓
75-10	↓	↓	572	↓
75-11	↓	↓	576	↓
75-12	↓	↓	582	↓
75-13	↓	↓	586	↓
75-14	↓	↓	574	↓
75-15	↓	↓	538	↓
75-16	↓	↓	532	↓
75-17	↓	↓	530	↓
75-18	↓	↓	536	↓
75-19	↓	↓	569	↓
75-20	↓	↓	543	↓
75-21	↓	↓	570	↓
75-22	↓	↓	578	↓
75-23	↓	↓	574	↓
75-24	↓	↓	553	↓
75-25	↓	↓	550	↓
75-26	↓	↓	546	↓
75 27	↓	↓	544	↓
75-28	↓	↓	520	↓
75-29	↓	↓	518	↓
75-30	NA	NA	504	BORROW, 16" DIA
75-31	12+60	370 US	475	SPT, 16" DIA
75-32	11+40	370 US	475	↓
75-33	10+20	370 US	475	↓
75-34	9+00	370 US	475	↓
75-35	NA	NA	548	BORROW, 16" DIA
75-36	↓	↓	552	↓
75-37	↓	↓	546	↓
75-38	↓	↓	512	↓
75 39	↓	↓	517	↓
75-40	↓	↓	542	↓
75-41	↓	↓	543	↓
75-42	↓	↓	530	↓
75-43	↓	↓	521	↓
75-44	↓	↓	500	↓
75-45	↓	↓	512	↓
75-46	↓	↓	511	↓
75-47	↓	↓	506	↓
75-48	↓	↓	518	↓
75-49	20+00	520 US	480	SPT, 16" DIA
75-50	14+85	565 US	492	↓
75-51	10+10	525 US	482	↓
75-52	7+50	400 US	475	↓
75-53	12+60	410 US	474	↓
75-54	17+40	380 US	475	↓
75-55	20+00	310 US	476	↓
75-56	20+00	375 US	475	↓
75-57	15+00	310 US	476	↓
75-58	5+00	310 US	476	↓
75-59	5+00	175 US	510	↓
75-60	7+50	175 US	510	↓
75-61	15+00	175 US	510	↓
75-62	10+00	175 US	510	↓
75-63	17+50	175 US	510	↓
75-64	5+00	470 DS	484	↓
75-65	7+50	470 DS	482	↓
75-66	7+50	325 DS	484	↓
75-67	10+00	310 US	476	↓
75-68	10+00	470 DS	485	↓
75-69	12+50	470 DS	486	↓
75-70	15+00	470 DS	486	↓
75-71	20+00	470 DS	486	↓
9F	13+20	390 US		
10F	8+10	385 US		
11F	8+10	290 US		
12F	13+20	290 US		
13F	14+10	365 US		
14F	12+00	365 US		
15F	10+70	365 US		
16F	13+20	430 DS		
17F	15+00	460 DS		
18F	12+00	465 DS		
19F	11+00	465 DS		
20F	14+00	325 DS		
21F	12+00	325 DS		
22F	12+52	0		
23F	8+00	175 US		
24F	12+00	175 US		
25F	8+25	385 US		
26F	7+00	385 US		
27F	9+05	405 US		
28F	10+35	420 US		
29F	12+40	390 US		
30F	8+00	390 US		
31F	12+10	290 US		
32F	12+85	390 US		
33F	12+85	410 US		
34F	12+40	390 US		
35F	12+50	385 US		
37F	10+00	10 DS		
38F	9+73	10 DS		
39F	17+70	385 US		
40F	17+80	400 US		
41F	15+00	10 DS		
42F	7+50	10 DS		
43F	17+50	10 DS		
44F	20+00	10 DS		
45F	10+00	135 DS		
46F	20+00	135 DS		
47F	15+00	135 DS		
48F	7+50	135 DS		

T.H. 72-1



FAT CLAY, grey-brown, stiff.

SANDY SILT, brown, medium dense, added revert to hole.

SILTY SAND, brown, medium dense, gravel to 1 1/2" max.

CLAYEY SAND, grey-brown, medium dense, cobbles to 5" max.

SILTY SAND-CLAYEY SAND, grey, medium dense, gravel

SILTY GRAVELLY SAND, grey, medium dense, gravel to 1 1/2" max.

GRAVELLY SAND-SILTY GRAVELLY SAND, light brown, medium dense, cobbles to 5" max., a 2" CH lens at 25.5'.

SAND-SILTY SAND, light brown, loose.

SAND, light brown, medium dense to dense.

FAT CLAY, dark grey with brown organics (OL), soft.

SAND-SILTY SAND, light brown, medium dense, gravel to 1 1/2" max.

SAND, light brown, medium dense, gravel to 1 1/2" max

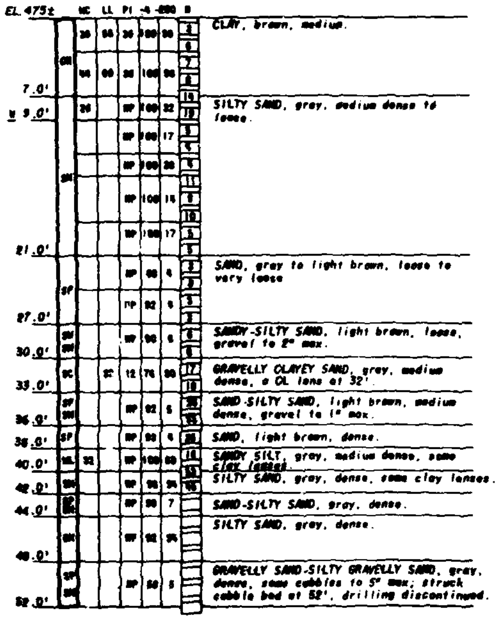
GRAVELLY-SAND-SILTY GRAVELLY SAND, light brown, medium dense, some 4" cobbles.

SAND-SILTY SAND, light brown, medium dense.

SILTY SAND, light brown, medium dense.

SAND, light brown, medium dense.

T.H. 72-2



CLAY, brown, medium.

SILTY SAND, grey, medium dense to loose.

SAND, grey to light brown, loose to very loose

SANDY-SILTY SAND, light brown, loose, gravel to 2" max.

GRAVELLY CLAYEY SAND, grey, medium dense, a CL lens at 32'.

SAND-SILTY SAND, light brown, medium dense, gravel to 1" max.

SAND, light brown, dense.

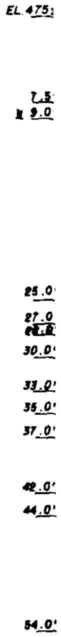
SANDY SILT, gray, medium dense, some clay lenses.

SILTY SAND, gray, dense, some clay lenses.

SAND-SILTY SAND, gray, dense.

SILTY SAND, gray, dense.

GRAVELLY SAND-SILTY GRAVELLY SAND, gray, dense, some cobbles to 5" max; struck cobble bed at 52', drilling discontinued.



BORING NUMBER	STATION NUMBER	OFFSET FROM ℄ (FEET)	SURFACE ELEV. (FEET)	TYPE OF BORING
9F	13+20	380 US	475	3" UNDISTURBED
10F	8+10	385 US	475	↓
11F	8+10	290 US	476	↓
12F	13+20	290 US	476	↓
13F	14+10	385 US	475	↓
14F	12+00	365 US	475	↓
15F	10+70	365 US	475	↓
16F	13+20	430 DS	485	↓
17F	15+00	460 DS	485	3" UNDIST, & SPT
18F	12+00	465 DS	485	↓
19F	11+90	465 DS	485	SPT, 3" DIA
20F	14+90	325 DS	485	3" UNDIST, & SPT
21F	12+00	325 DS	485	3" UNDISTURBED
22F	12+52	0	566	↓
23F	8+00	175 US	510	↓
24F	12+00	175 US	510	↓
25F	8+25	385 US	475	↓
26F	7+00	385 US	475	↓
27F	9+06	405 US	475	↓
28F	10+35	420 US	476	↓
29F	12+40	380 US	476	3" UNDISTURBED
30F	8+00	380 US	476	3" DIA, NO RECOVERY
31F	12+10	290 US	476	3" UNDISTURBED
32F	12+65	380 US	476	↓
33F	12+65	410 US	476	3" DIA, NO RECOVERY
34F	12+40	380 US	476	3" UNDISTURBED
35F	12+50	385 US	476	3" DIA, NO RECOVERY
37F	10+00	10 DS	566	3" UNDIST OF CORE
38F	9+73	10 DS	566	SPT, 3" DIA
39F	17+70	385 US	476	↓
40F	17+80	400 US	476	↓
41F	15+00	10 DS	566	↓
42F	7+50	10 DS	566	↓
43F	17+50	10 DS	566	↓
44F	20+00	10 DS	566	↓
45F	10+00	135 DS	525	↓
46F	20+00	135 DS	525	↓
47F	15+00	135 DS	525	3" UNDIST, & SPT
48F	7+50	135 DS	525	SPT, 3" DIA

UNIFIED SOIL CLASSIFICATION SYSTEM

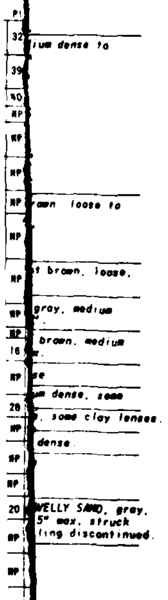
MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAME
COARSE GRAINED SOILS More than half of material is larger than no. 200 sieve size.	GRAVELS More than half of coarse fraction is larger than no. 4 sieve size.	Clean gravels	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.
		Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS More than half of coarse fraction is smaller than no. 4 sieve size.	Clean sands	SW	Well-graded sands, gravelly sands, little or no fines.
			SP	Poorly-graded sands, gravelly sands, little or no fines.
		Sands with fines	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS More than half of material is smaller than no. 200 sieve size.	SILTS AND CLAYS	Low liquid limit.	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts, with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
		High liquid limit.	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
Highly organic soils			Pt	Peat and other highly organic soils.

NOTES:

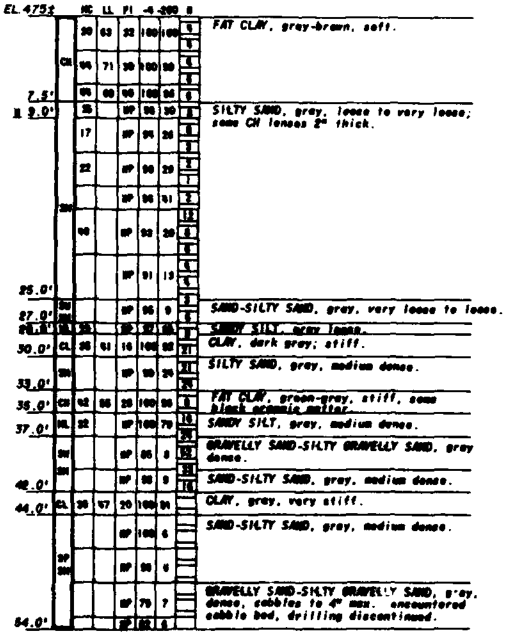
1. Boundary Classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example, GW-GC, well-graded gravel-sand mixture with clay binder.
2. All sieve sizes on this chart are U. S. Standard.
3. The terms "silt" and "clay" are used respectively to distinguish materials exhibiting lower plasticity from those with higher plasticity. The minus no. 200 sieve material is silt if the liquid limit and plasticity index plot below the "A" line on the plasticity chart (Table VI, Military Standard 619B), and is clay if the liquid limit and plasticity index plot above the "A" line on the chart.
4. For a complete description of the Unified Soil Classification System, see "Military Standard 619B".
5. Gradations are conducted on minus 3-inch material.
6. For location of test holes see plate [illegible].
7. TH 72-1 through 3 were drilled in 1972 with a 18-inch diameter bucket-type power auger.
8. All holes were drilled to desired depth, except when indicated otherwise.

LEGEND

TH 72-1	NUMBER OF TEST HOLE
MC	FIELD MOISTURE CONTENT IN PERCENT OF DRY WEIGHT.
LL	LIQUID LIMIT.
PI	PLASTICITY INDEX (LIQUID LIMIT MINUS PLASTIC LIMIT).
NP	NONPLASTIC
-4	PERCENT OF MATERIAL BY WEIGHT PASSING NO. 4 SIEVE.
-200	PERCENT OF MATERIAL BY WEIGHT PASSING NO. 200 SIEVE.
N	NUMBER OF BLOWS OF A 140-POUND DROPHAMMER FALLING 30 INCHES REQUIRED TO DRIVE A SAMPLING SPOON ONE FOOT. OUTSIDE DIAMETER OF SPOON IS 2 INCHES; INSIDE DIAMETER IS 1-3/8 INCHES. PROCEDURE IS CALLED STANDARD PENETRATION TEST.
W	DEPTH TO WATER
NA	NOT APPLICABLE
US	UPSTREAM
DS	DOWNSTREAM
SPT	STANDARD PENETRATION TEST



T.H. 72-3



FAT CLAY, grey-brown, soft.

SILTY SAND, grey, loose to very loose; some CH lenses 2" thick.

SAND-SILTY SAND, grey, very loose to loose.

SANDY SILT, grey loose.

CLAY, dark grey; stiff.

SILTY SAND, grey, medium dense.

FAT CLAY, green-grey, stiff, some black organic matter.

SANDY SILT, grey, medium dense.

GRAVELLY SAND-SILTY GRAVELLY SAND, grey dense.

SAND-SILTY SAND, grey, medium dense.

CLAY, grey, very stiff.

SAND-SILTY SAND, grey, medium dense.

GRAVELLY SAND-SILTY GRAVELLY SAND, grey, dense, cobbles to 4" max. encountered cobble bed, drilling discontinued.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SUMMARY OF BORINGS
SOIL LOGS
T.H.72-1 THRU T.H.72-3

SUBMITTED BY:

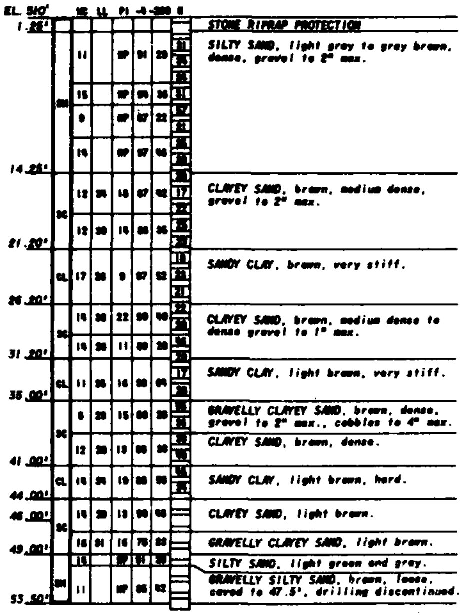
DATE APPROVED:

SPEC. NO. DACW09-____ B-____

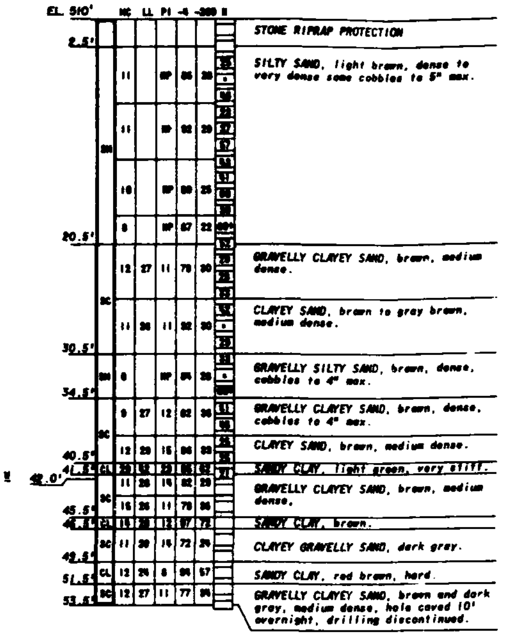
DISTRICT FILE NO.

SHEET

T.H. 72-4

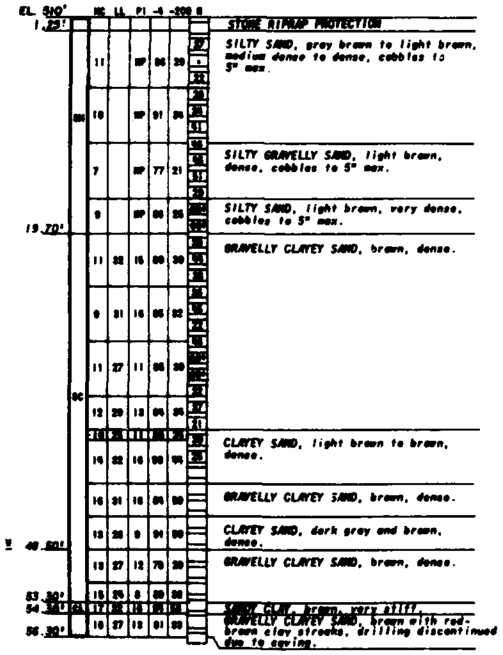


T.H. 72-5



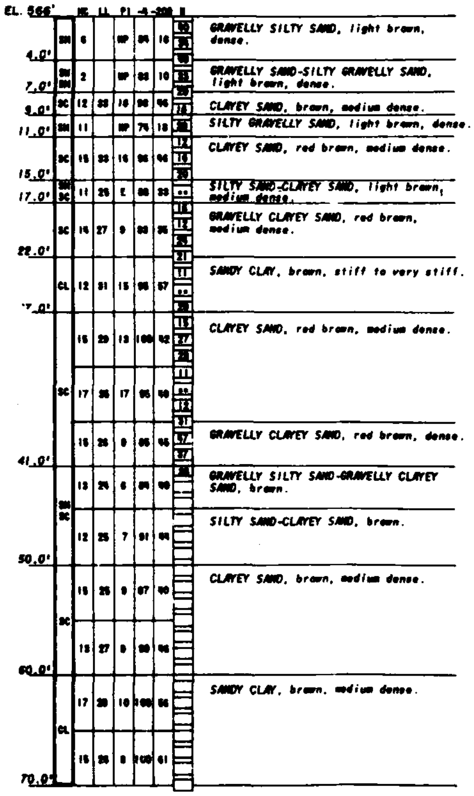
* cobble

T.H. 72-6

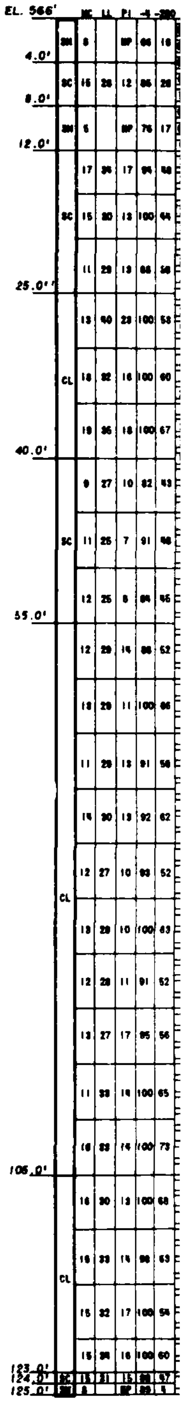


* cobble

T.H. 72-7

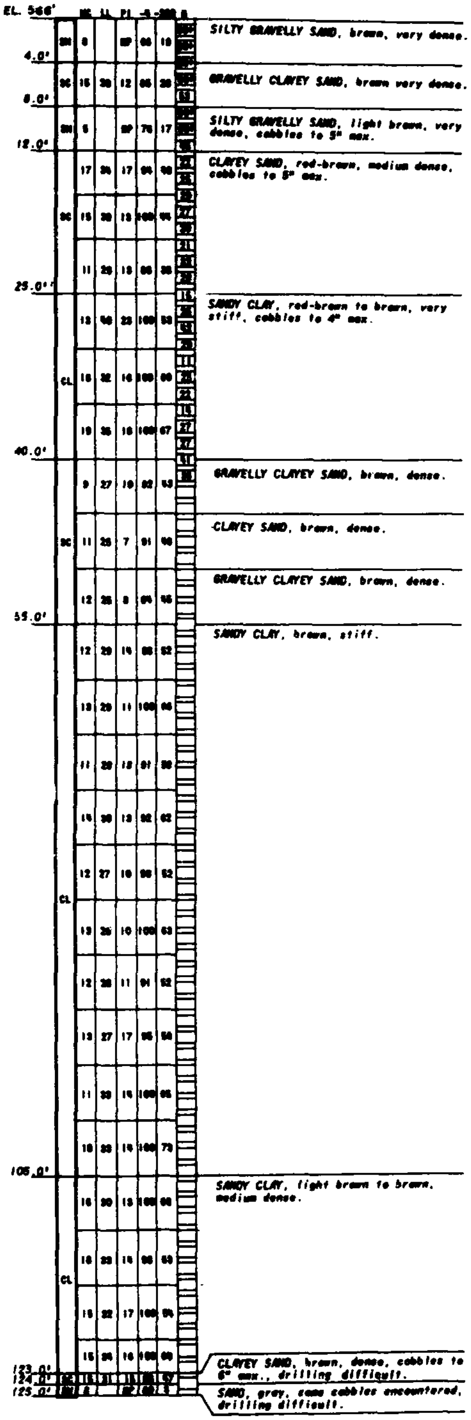


** no test, undisturbed samples taken.

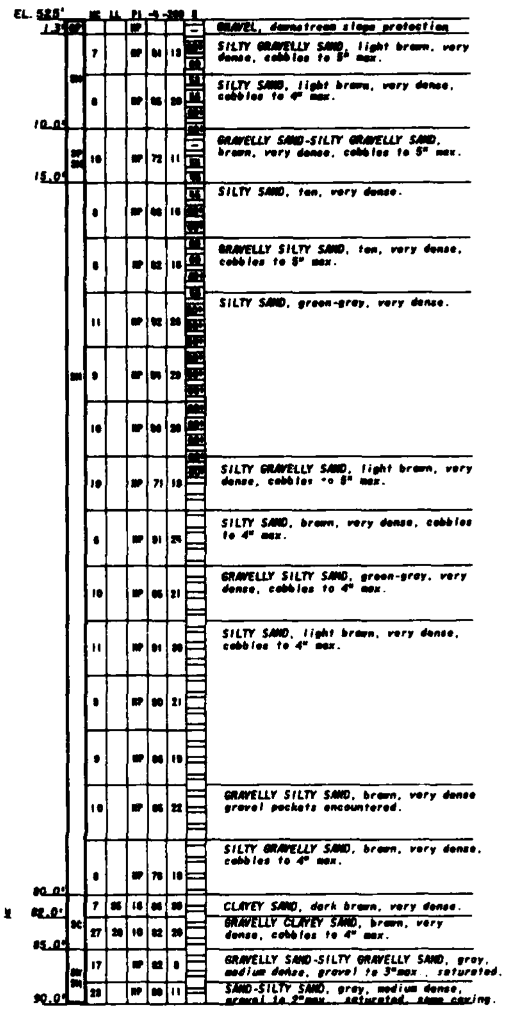


VERT SCALE FEET

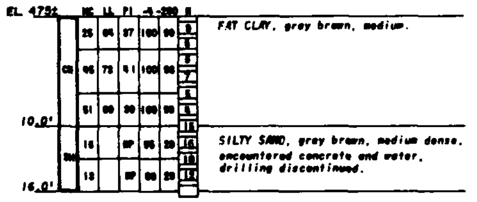
T.H. 72-8



T.H. 72-10



T.H. 72-1A



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

NOTES:

1. FOR LOCATION OF TEST HOLES SEE PLATE 18.
2. FOR LEGEND SEE PLATE 25.
3. TH 72-4 THROUGH 8, 72-10 and 72-1A WERE DRILLED DURING 1972 WITH A 16-INCH DIAMETER BUCKET-TYPE POWER AUGER.
4. ALL HOLES DRILLED TO DESIRED DEPTH, EXCEPT WHEN INDICATED OTHERWISE

SCALE FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.H.72-4 THRU T.H.72-8
T.H.72-10 AND T.H.72-1A

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

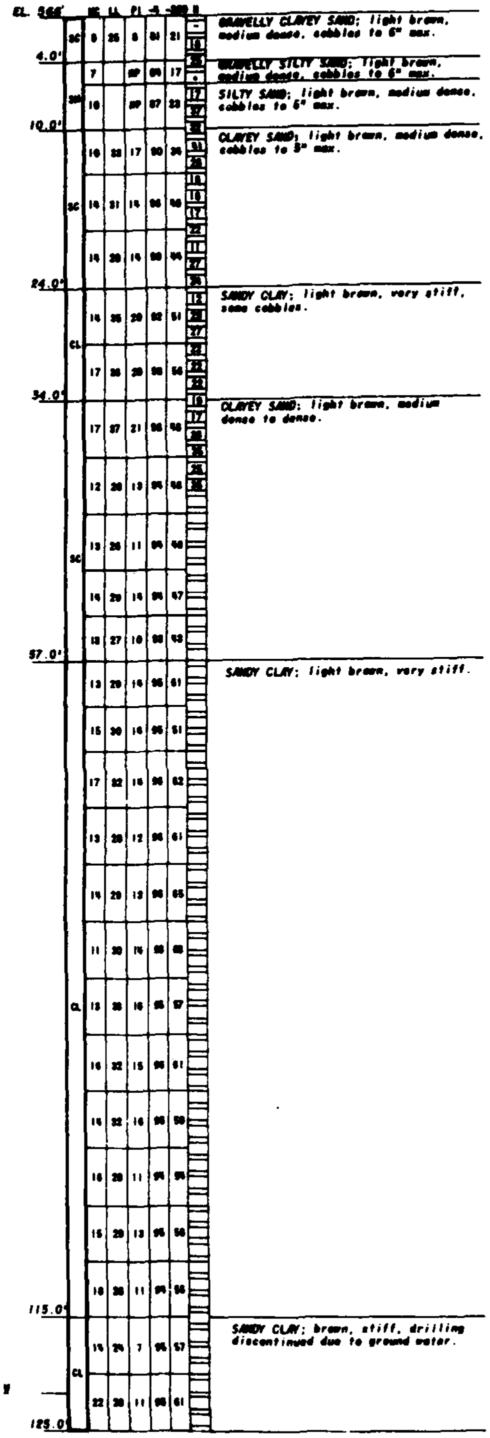
PLATE B-[illegible]

1

2

U.S. ARMY ENGINEER DISTRICT

T.H. 72-9



GRAVELLY CLAYEY SAND; light brown, medium dense, cobbles to 6" max.

GRAVELLY SILTY SAND; light brown, medium dense, cobbles to 6" max.

SILTY SAND; light brown, medium dense, cobbles to 6" max.

CLAYEY SAND; light brown, medium dense, cobbles to 3" max.

SANDY CLAY; light brown, very stiff, some cobbles.

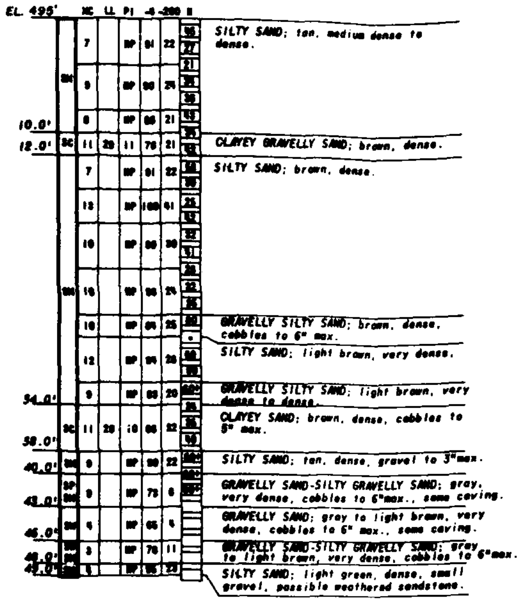
CLAYEY SAND; light brown, medium dense to dense.

SANDY CLAY; light brown, very stiff.

SANDY CLAY; brown, stiff, drilling discontinued due to ground water.

* cobble

T.H. 72-11



SILTY SAND; tan, medium dense to dense.

CLAYEY GRAVELLY SAND; brown, dense.

SILTY SAND; brown, dense.

GRAVELLY SILTY SAND; brown, dense, cobbles to 6" max.

SILTY SAND; light brown, very dense.

GRAVELLY SILTY SAND; light brown, very dense to dense.

CLAYEY SAND; brown, dense, cobbles to 5" max.

SILTY SAND; tan, dense, gravel to 3" max.

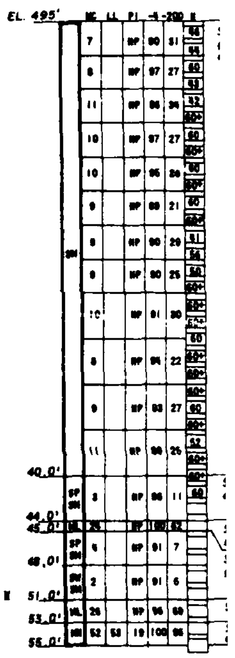
GRAVELLY SAND-SILTY GRAVELLY SAND; gray, very dense, cobbles to 6" max., some caving.

GRAVELLY SAND; gray to light brown, very dense, cobbles to 6" max., some caving.

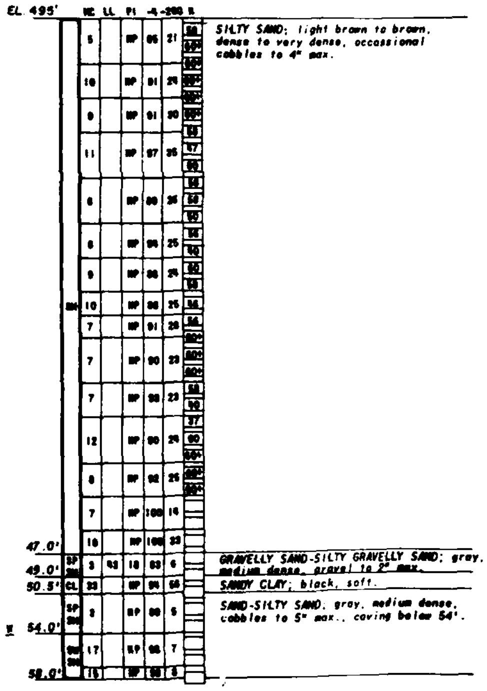
GRAVELLY SAND-SILTY GRAVELLY SAND; gray to light brown, very dense, cobbles to 6" max.

SILTY SAND; light green, dense, small gravel, possible weathered sandstone.

T.H



T.H. 72-13



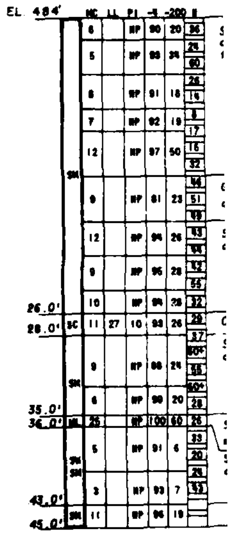
SILTY SAND; light brown to brown, dense to very dense, occassional cobbles to 4" max.

GRAVELLY SAND-SILTY GRAVELLY SAND; gray, medium dense, gravel to 2" max.

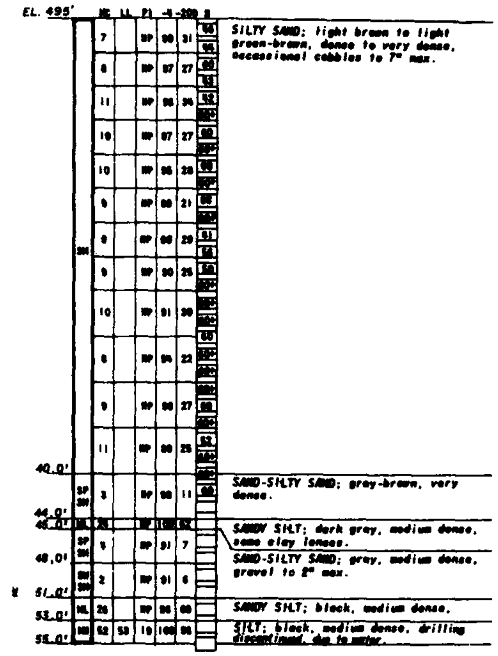
SANDY CLAY; black, soft.

SAND-SILTY SAND; gray, medium dense, cobbles to 5" max., caving below 54'.

T.H



T.H. 72-12



SILTY SAND; light brown to light green-brown, dense to very dense, occassional cobbles to 7" max.

SAND-SILTY SAND; grey-brown, very dense.

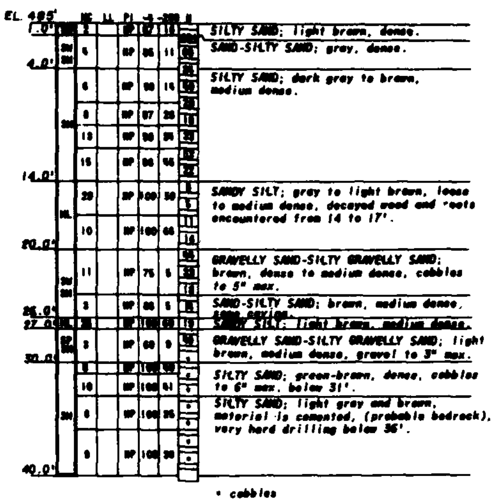
SANDY SILT; dark gray, medium dense, some clay lenses.

SAND-SILTY SAND; grey, medium dense, gravel to 2" max.

SANDY SILT; black, medium dense.

SILT; black, medium dense, drilling discontinued, due to water.

T.H. 72-15



SILTY SAND; light brown, dense.

SAND-SILTY SAND; gray, dense.

SILTY SAND; dark gray to brown, medium dense.

SANDY SILT; gray to light brown, loose to medium dense, decayed wood and roots encountered from 14 to 17'.

GRAVELLY SAND-SILTY GRAVELLY SAND; brown, dense to medium dense, cobbles to 5" max.

SAND-SILTY SAND; brown, medium dense, some caving.

SANDY SILT; light brown, medium dense.

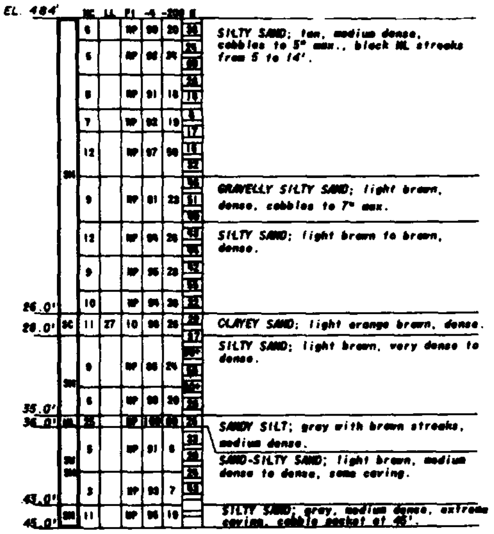
GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, medium dense, gravel to 3" max.

SILTY SAND; green-brown, dense, cobbles to 6" max. below 31'.

SILTY SAND; light gray and brown, material is cemented, (probable bedrock), very hard drilling below 36'.

• cobbles

T.H. 72-14



SILTY SAND; tan, medium dense, cobbles to 5" max., black ML streaks from 5 to 14'.

GRAVELLY SILTY SAND; light brown, dense, cobbles to 7" max.

SILTY SAND; light brown to brown, dense.

CLAYEY SAND; light orange brown, dense.

SILTY SAND; light brown, very dense to dense.

SANDY SILT; gray with brown streaks, medium dense.

SAND-SILTY SAND; light brown, medium dense to dense, some caving.

SILTY SAND; gray, medium dense, extreme caving, cobble pocket at 45'.

NOTES:

1. FOR LOCATION OF TEST HOLES SEE PLATE 18.
2. FOR LEGEND SEE PLATE 25.
3. TH 72-9 AND 72-11 THROUGH 15 WERE DRILLED DURING 1972 WITH A 16-INCH DIAMETER BUCKET-TYPE POWER AUGER.
4. ALL HOLES DRILLED TO DESIRED DEPTH, EXCEPT WHEN INDICATED OTHERWISE.

VERT SCALE 0 4 8 12 16 20 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS

T.H. 72-9, T.H. 72-11 THRU T.H. 72-15

SUBMITTED BY:

DATE APPROVED:

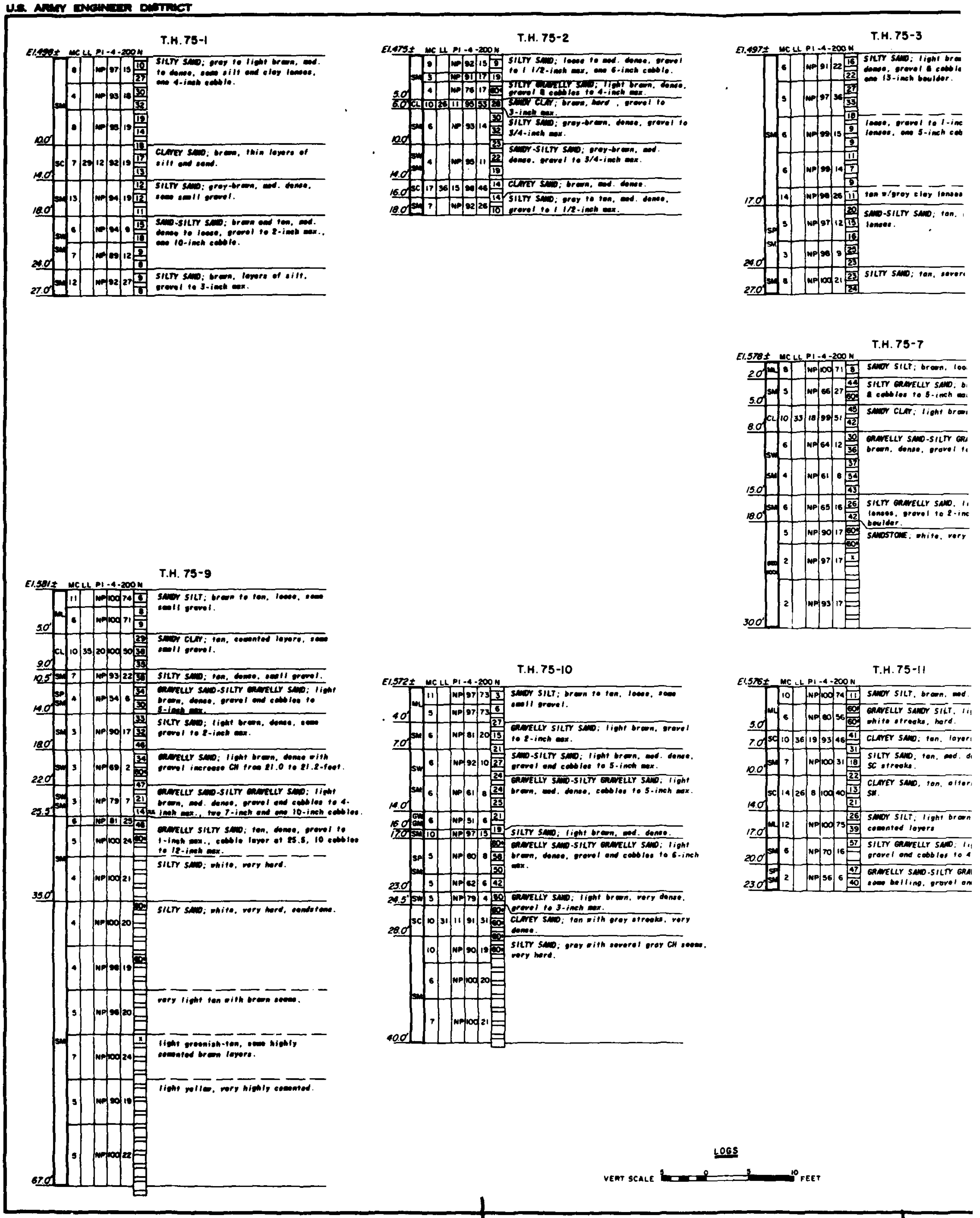
SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

2

U.S. ARMY ENGINEER DISTRICT



T.H. 75-1

El.498±		MC	LL	PI	-4	-200	N	
	SM	8		NP	97	15	10 27	SILTY SAND; grey to light brown, med. to dense, some silt and clay lenses, one 4-inch cobble.
		4		NP	93	18	30 32	
10.0'		8		NP	95	19	19 14	
14.0'	SC	7	29	12	92	19	18 17 13	CLAYEY SAND; brown, thin layers of silt and sand.
18.0'	SM	13		NP	94	19	12 12 11	SILTY SAND; grey-brown, med. dense, some small gravel.
	SM	6		NP	94	9	15 18	SAND-SILTY SAND; brown and tan, med. dense to loose, gravel to 2-inch max., one 10-inch cobble.
24.0'	SM	7		NP	89	12	9 8	
27.0'	SM	12		NP	92	27	9 8	SILTY SAND; brown, layers of silt, gravel to 3-inch max.

T.H. 75-2

El.475±		MC	LL	PI	-4	-200	N	
	SM	9		NP	92	15	9	SILTY SAND; loose to med. dense, gravel to 1 1/2-inch max, one 6-inch cobble.
		3		NP	91	17	19	
5.0'		4		NP	76	17	60*	SILTY GRAVELLY SAND; light brown, dense, gravel & cobbles to 4-inch max.
6.0'	CL	10	26	11	95	53	28	SANDY CLAY; brown, hard , gravel to 3-inch max.
10.0'	SM	6		NP	93	14	30 32	SILTY SAND; grey-brown, dense, gravel to 3/4-inch max.
14.0'	SW SM	4		NP	95	11	25 22 19	SANDY-SILTY SAND; grey-brown, med. dense. gravel to 3/4-inch max.
16.0'	SC	17	36	15	98	46	14	CLAYEY SAND; brown, med. dense.
18.0'	SM	7		NP	92	26	14 10	SILTY SAND; grey to tan, med. dense, gravel to 1 1/2-inch max.

T.H. 75-3

El.497±		MC	LL	PI	-4	-200	N	
	SM	6		NP	91	22	16 22	SILTY SAND; light bro dense, gravel & cobbl one 13-inch boulder.
		5		NP	97	36	27 33	
		6		NP	99	15	18 9 9	loose, gravel to 1-inc lenses, one 5-inch cob
		6		NP	99	14	11 7 9	
17.0'		14		NP	98	26	11	tan w/grey clay lenses
	SP SM	5		NP	97	12	20 15 16	SAND-SILTY SAND; tan, lenses.
24.0'		3		NP	98	9	23 23	
27.0'	SM	8		NP	100	21	23 24	SILTY SAND; tan, sever

T.H. 75-7

El.578±		MC	LL	PI	-4	-200	N	
2.0'	ML	8		NP	100	71	8	SANDY SILT; brown, loo
5.0'	SM	5		NP	66	27	44 60*	SILTY GRAVELLY SAND; b & cobbles to 5-inch ma
8.0'	CL	10	33	18	99	51	45 42	SANDY CLAY; light brow
	SW	6		NP	64	12	30 36	GRAVELLY SAND-SILTY GR brown, dense, gravel t
15.0'	SM	4		NP	61	8	37 54 43	
18.0'	SM	6		NP	65	16	26 42	SILTY GRAVELLY SAND, l lenses, gravel to 2-inc boulder.
		5		NP	90	17	60* 60*	SANDSTONE, white, very
	[illegible]	2		NP	97	17	x	
30.0'		2		NP	93	17		

T.H. 75-9

El.581±		MC	LL	PI	-4	-200	N	
	ML	11		NP	100	74	6	SANDY SILT; brown to tan, loose, some small gravel.
5.0'		6		NP	100	71	8 9	
9.0'	CL	10	35	20	100	50	29 38 35	SANDY CLAY; tan, cemented layers, some small gravel.
10.5'	SM	7		NP	93	22	38	SILTY SAND; tan, dense, small gravel.
14.0'	SP SM	4		NP	54	6	34 30	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, dense, gravel and cobbles to 5-inch max.
18.0'	SM	3		NP	90	17	33 32 48	SILTY SAND; light brown, dense, some gravel to 2-inch max.
22.0'	SW	3		NP	69	2	34 60*	GRAVELLY SAND; light brown, dense with gravel increase CH from 21.0 to 21.2-feet.
25.5'	SW SM	3		NP	79	7	47 21 14	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, med. dense, gravel and cobbles to 4-inch max., two 7-inch and one 10-inch cobbles.
		6		NP	81	25	48	GRAVELLY SILTY SAND; tan, dense, gravel to 1-inch max., cobble layer at 25.5, 10 cobbles to 12-inch max.
	SM	5		NP	100	24	60*	
35.0'		4		NP	100	21		SILTY SAND; white, very hard.
		4		NP	100	20	60*	SILTY SAND; white, very hard, sandstone.
		4		NP	98	19	60*	
		5		NP	98	20		very light tan with brown seams.
	SM	7		NP	100	24	x	light greenish-tan, some highly cemented brown layers.
		5		NP	90	19		light yellow, very highly cemented.
67.0'		5		NP	100	22		

T.H. 75-10

El.572±		MC	LL	PI	-4	-200	N	
	ML	11		NP	97	73	3	SANDY SILT; brown to tan, loose, some small gravel.
4.0'		5		NP	97	73	6	
7.0'	SM	6		NP	81	20	27 15	GRAVELLY SILTY SAND; light brown, gravel to 2-inch max.
	SW	6		NP	92	10	21 27	SAND-SILTY SAND; light brown, med. dense, gravel and cobbles to 5-inch max.
14.0'	SM	6		NP	61	8	24 24 25	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, med. dense, cobbles to 5-inch max.
16.0'	GW GM	6		NP	51	6	21	
17.0'	SM	10		NP	97	15	19	SILTY SAND; light brown, med. dense.
	SP SM	5		NP	80	8	60* 58 50	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, dense, gravel and cobbles to 6-inch max.
23.0'		5		NP	62	6	42	
24.5'	SW	3		NP	79	4	50	GRAVELLY SAND; light brown, very dense, gravel to 3-inch max.
28.0'	SC	10	31	11	91	31	60* 60*	CLAYEY SAND; tan with gray streaks, very dense.
		10		NP	90	19	60* 60*	SILTY SAND; gray with several gray CH seams, very hard.
	SM	6		NP	100	20		
40.0'		7		NP	100	21		

T.H. 75-11

El.576±		MC	LL	PI	-4	-200	N	
	ML	10		NP	100	74	11	SANDY SILT, brown, med.
5.0'		6		NP	80	56	60* 60*	GRAVELLY SANDY SILT, li white streaks, hard.
7.0'	SC	10	36	19	93	46	41	CLAYEY SAND; tan, layer
10.0'	SM	7		NP	100	31	31 18	SILTY SAND; tan, med. d SC streaks.
14.0'	SC	14	26	8	100	40	22 13 21	CLAYEY SAND, tan, alter SM.
17.0'	ML	12		NP	100	75	26 39	SANDY SILT; light brown cemented layers
20.0'	SM	6		NP	70	16	57	SILTY GRAVELLY SAND; li gravel and cobbles to 4
23.0'	SP SM	2		NP	56	6	47 40	GRAVELLY SAND-SILTY GRA some belling, gravel an

LOGS

T.H. 75-3

El.497±		MC	LL	PI	-4	-200	N	
	SM	6		NP	91	22	16 22	SILTY SAND; light brown, med. dense to dense, gravel & cobbles to 7 inches, one 13-inch boulder.
		5		NP	97	36	27 33	
		6		NP	99	15	18 9 9	loose, gravel to 1-inch max., thin clay lenses, one 5-inch cobble.
		6		NP	99	14	11 7 9	
17.0'		14		NP	98	26	11	tan w/grey clay lenses.
	SP SM	5		NP	97	12	20 15 16	SAND-SILTY SAND; tan, med. dense, sc lenses.
24.0'		3		NP	98	9	25 23	
27.0'	SM	8		NP	100	21	23 24	SILTY SAND; tan, several clay lenses.

T.H. 75-4

El.496±		MC	LL	PI	-4	-200	N	
	SM	8		NP	97	14	6	SILTY SAND; light brown to tan, loose to med. dense, gravel to 2 1/2-inch max.
5.0'		7		NP	98	32	20 21	
8.0'	SW SM	5		NP	92	11	22 22	SAND-SILTY SAND; light brown, med. dense, gravel & one 4-inch cobble.
	SM	5		NP	87	13	18 13	SILTY SAND; brown, med. dense to loose, gravel & cobbles to 5-inch max., several clay lenses.
		9		NP	98	26	7 10 5	
		6		NP	86	24	24 7	
22.0'		17		NP	88	24	8 13	
24.0'	CL	16	37	19	96	56	10 26	SANDY CLAY; grey, several small cobbles.
27.0'	SM	5		NP	98	17	19 18	SILTY SAND; grey, med. dense.

T.H. 75-7

El.578±		MC	LL	PI	-4	-200	N	
2.0'	ML	8		NP	100	71	8	SANDY SILT; brown, loose.
5.0'	SM	5		NP	66	27	44 60+	SILTY GRAVELLY SAND; brown, dense, gravel & cobbles to 5-inch max.
9.0'	CL	10	33	18	99	51	45 42	SANDY CLAY; light brown, very hard.
	SW	6		NP	64	12	30 36	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, dense, gravel to 3-inch max.
15.0'	SM	4		NP	61	8	37 54 43	
18.0'	SM	6		NP	65	16	26 42	SILTY GRAVELLY SAND; light brown, clay lenses, gravel to 2-inch max., one 17-inch boulder.
	BED ROCK	5		NP	90	17	60+ 60+	SANDSTONE, white, very hard.
		2		NP	97	17	x	
30.0'		2		NP	93	17		

T.H. 75-8

El.568±		MC	LL	PI	-4	-200	N	
2.0'	CL	10	27	12	100	70	16	SANDY CLAY; brown, medium
	SC	8	37	21	97	43	46 32	CLAYEY SAND; tan, dense.
9.0'		6	26	9	82	39	26 27 26	GRAVELLY CLAYEY SAND; tan, med. dense.
12.0'	ML	13	35	5	100	93	60+ 41	SILT, tan, cemented.
	SM	4		NP	100	31	37	SILTY SAND; tan, dense.
17.0'		2		NP	71	15	60+ 58	SILTY GRAVELLY SAND; tan, very dense, gravel to 2-inch max.
19.0'	SP SM	2		NP	64	6	43	GRAVELLY SAND-SILTY GRAVELLY SAND; tan, cobbles to 4-inch max.
23.0'	SM	3		NP	65	14	37 60+ 34	SILTY GRAVELLY SAND; tan, dense, gravel & cobbles to 5-inch max.
26.0'	SC	10	31	11	90	49	60+ 60+	CLAYEY SAND; tan, very dense, gravel to 1/2-inch max.
27.0'	SM	4			69	21	40	SILTY GRAVELLY SAND; tan, dense, cobbles to 10-inch max, one 13-inch boulder.

T.H. 75-11

El.576±		MC	LL	PI	-4	-200	N	
	ML	10		NP	100	74	11	SANDY SILT; brown, med. dense.
5.0'		6		NP	80	56	60+ 60+	GRAVELLY SANDY SILT, light brown with white streaks, hard.
7.0'	SC	10	36	19	93	46	41	CLAYEY SAND; tan, layers of SM, dense.
10.0'	SM	7		NP	100	31	31 18	SILTY SAND; tan, med. dense, some SC streaks.
14.0'	SC	14	26	8	100	40	22 13 21	CLAYEY SAND, tan, alternating layers of SM.
17.0'	ML	12		NP	100	75	26 39	SANDY SILT, light brown and tan, some cemented layers.
20.0'	SM	6		NP	70	16	57	SILTY GRAVELLY SAND; light brown, dense, gravel and cobbles to 4-inch max
23.0'	SP SM	2		NP	56	6	47 40	GRAVELLY SAND-SILTY GRAVELLY SAND, tan, dense some belling, gravel and cobbles to 6-inch max.

Notes:

1. TH 75-1 through 75-11 were drilled during January 1975 with a 16-inch diameter bucket-type power auger.
2. For locations of test holes 75-1 through 75-4 see Plate 18. All other holes were drilled in borrow areas
3. For legend see Plate 25.

LOGS

5 10 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE I GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.H. 75-1 THRU T.H. 75-4
T.H. 75-7 THRU T.H. 75-11

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

PLATE B-28

1

2

U.S. ARMY ENGINEER DISTRICT

T.H. 75-12

El.582±		MC	LL	PI	-4	-200	N	
2.0'	ML	8		NP	100	77	5	SANDY SILT; brown, loose.
	CL	7	24	8	100	66	35 34 40	SANDY CLAY; light brown, hard.
8.0'		11	38	24	100	61	35	
	SM	13		NP	100	47	19 24 23	SILTY SAND; light brown, very fine, some SC lenses, med. dense.
14.0'		18		NP	100	50	42	tan, some cemented lenses.
18.0'	SP SW	3		NP	69	7	54 26 54	GRAVELLY SAND-SILTY GRAVELLY SAND; tan, med. dense to dense, gravel to 3" max.
22.0'	SW	2		NP	59	4	30 18 29	GRAVELLY SAND; tan, med. dense to dense, gravel to 3" max., some balling.

T.H. 75-13

El.586±		MC	LL	PI	-4	-200	N	
2.0'	ML	9		NP	100	72	6	SANDY SILT; brown.
5.0'	ML CL	6	23	7	97	66	60+ 60	SANDY SILT-SANDY CLAY; light brown, very hard, some gravel.
7.0'	SM	8		NP	82	27	60+ 39	GRAVELLY SILTY SAND; light brown, very dense, gravel to 2 1/2" max.
11.0'	CL	9	26	11	100	50	38 27	SANDY CLAY; light brown, dense, SM and SC layers.
	SM	8		NP	100	42	21	SILTY GRAVELLY SAND; light brown, med dense, gravel to 2 1/2", cobbles to 4" max.
		6		NP	84	13	25 24	
16.0'		7		NP	63	15		
20.0'	CL	15	43	21	100	82	33 34 36	SANDY CLAY; light brown and gray, hard.
23.0'	ML	13		NP	100	82	42 41	SANDY SILT; tan, very hard, some CL lenses.
24.0'	SM	4		NP	100	31	37	SILTY SAND; tan, dense, some gravel.
26.0'	SW SM	1		NP	85	6	33 21	GRAVELLY SAND-SILTY GRAVELLY SAND; tan, gravel to 2 1/2" max.

T.H. 75-14

El.574±		MC	LL	PI	-4	-200	N	
2.0'	CL	14	30	12	100	80	5	SANDY CLAY; light brow
6.0'	SM	7		NP	100	14	8 19 31	SILTY SAND; tan, very cemented layers.
8.0'	ML	7		NP	95	55	25	SANDY SILT; tan, med.
9.5'	CL	19	34	13	100	72	16	SANDY CLAY; gray, very
13.0'	SP SM	4		NP	98	5	30 38	SAND-SILTY SAND; light some small gravel.
	SW SM	3		NP	75	6	28 32	GRAVELLY SAND-SILTY GRA brown, zones of fine w to 3" max., cobbles at
19.0'		3		NP	68	6	21	tan, med. dense.
22.0'	ML	22	38	12	96	70	19 44	SANDY SILT, light brow med. dense.

T.H. 75-16

El.532±		MC	LL	PI	-4	-200	N	
	ML	8		NP	96	66	10 11	SANDY SILT; light brown, med. dense, very fine.
6.0'		8		NP	98	63	14 31	light brown and grey, some cemented lenses.
8.0'	SM	4		NP	100	26	17	SILTY SAND; tan, very fine, ML lenses at 8 feet.
12.0'	SP	6		NP	59	4	29 37 29	GRAVELLY SAND; tan, gravel to 3" max.
14.0'	SW SM	2		NP	67	11	28	GRAVELLY SAND-SILTY GRAVELLY SAND, tan, gravel to 3" max.
15.0'	CL	17	44	22	97	66	27	SANDY CLAY; grey and light brown, very stiff.
20.0'	SW SM	2		NP	80	6	48 31	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, gravel to 3" max.

T.H. 75-17

El.530±		MC	LL	PI	-4	-200	N	
	ML	7		NP	100	76	15	SANDY SILT; brown, med. dense
4.0'		5		NP	100	74	29	tan, some cemented lens
8.0'	SC	6		NP	98	31	60+ 28 45	CLAYEY SAND, brown, very dense to med. dense.
	SP	4		NP	60	7	36 14 24	GRAVELLY SAND-SILTY GRAVELLY SAND; brown, dense, SC lens from 10.0 to 10.3 feet, gravel and cobbles 4" max
15.5'	SW	5		NP	55	7	60+ 60+	
16.0'	SC	24	40	19	82	33		GRAVELLY CLAYEY SAND, brown and gray, stiff
19.0'	SW SM	5		NP	82	9		GRAVELLY SAND-SILTY GRAVELLY SAND, brown, dense, very cohesive, gravel to 1 1/2" max
21.0'	SP SM	7		NP	97	10		SAND-SILTY SAND; gray, med. dense, very fine.

T.H. 75-18

El.536±		MC	LL	PI	-4	-200	N	
1.5'	SC	4	28	14	85	20	17	GRAVELLY CLAYEY SAND, b 2" max
5.0'	CL	11	30	11	98	57	7 20	SANDY CLAY, tan, med. t
9.0'	SW SM	2		NP	70	6	25 32 27	GRAVELLY SAND-SILTY GRA med. to dense, gravel a 4" max.
13.0'	SP	2		NP	56	3	19 20 19	GRAVELLY SAND, tan, med and cobbles to 4" max

T.H. 75-20

El.543±		MC	LL	PI	-4	-200	N	
2.0'	CL	14	48	27	100	89	28	SANDY CLAY, tan, hard
5.0'	SC	9	29	10	100	48	22 20	CLAYEY SAND; tan, med. dense.
7.0'	CH	17	58	30	100	91	24	FAT CLAY; brown and grey, very hard.
10.0'	ML	5		NP	100	66	37 38	SANDY SILT; tan to grey, dense, very fine grained.
11.0'	SM	3		NP	100	21	29	SILTY SAND; tan, dense, some small gravel
14.5'	SW SM	1		NP	88	5	31 28	SAND-SILTY SAND; tan, med. dense, gravel to 2" max.
16.0'	CH	20	33	11	100	[illegible]	33	FAT CLAY; grey and tan, hard.
18.0'	SP SM	2		NP	55	5	38	GRAVELLY SAND-SILTY GRAVELLY SAND; tan, dense, gravel and cobbles to 4" max.

T.H. 75-21

El.570±		MC	LL	PI	-4	-200	N	
3.0'	CH	4	24	9	91	57	-	FAT CLAY; tan, very hard, gravel to 2" max.
5.5'	SM	6		NP	76	25	-	GRAVELLY SILTY SAND; tan, gravel to 3" max., four 4" cobbles
9.0'	CH	8	30	14	98	52	60+ 53 39	FAT CLAY; tan, very hard, small gravel
	SM	6		NP	71	13	60	SILTY GRAVELLY SAND; tan, gravel to 2" max
13.0'		4		NP	92	18	31	SILTY SAND, dense, gravel to 1 1/2" max
	SP	4		NP	60	9	45 50 42	GRAVELLY SAND-SILTY GRAVELLY SAND, tan, dense, layers of SP and SM, cobbles to 4" max.
		4		NP	63	7	38	
24.0'	SM	4		NP	74	5	32 27 27 25	cobbles to 5" max.

T.H. 75-22

El.578±		MC	LL	PI	-4	-200	N	
2.0'	CL	8	24	8	99	57	34	SANDY CLAY, brown, hard
	SC	8	36	19	89	33	60+	CLAYEY SAND, brown, whi some gravel.
6.0'		7	28	12	83	22	60+ 56	GRAVELLY CLAYEY SAND, b
10.0'	SW SC	4	25	8	83	11	28 26	GRAVELLY SAND-CLAYEY GR brown, med. dense, grav
13.0'	SM	3		NP	88	18	18 15	SILTY SAND; light brown gravel to 2" max.
17.0'	SW SM	4		NP	80	11	26 26 27	GRAVELLY SAND-SILTY GRA brown, med. dense, 2" m SM lenses.
19.0'	ML	7		NP	99	53	18	SANDY SILT, light brown,
24.0'	SW SM	2		NP	84	6	28 34	GRAVELLY SAND-SILTY GRA light brown, dense, gra

LOGS

VERT SCALE 5 0 5 10 FEET

CORPS OF ENGINEERS

T.H. 75-14

El.574±

Depth	Soil	MC	LL	PI	-4	-200	N	Description
2.0'	CL	14	30	12	100	80	5	*SANDY CLAY; light brown to tan, soft*
6.0'	SM	7		NP	100	14	8 19 31	*SILTY SAND; tan, very fine, some cemented layers.*
8.0'	ML	7		NP	95	55	25	*SANDY SILT; tan, med. dense, small gravel*
9.5'	CL	19	34	13	100	72	16	*SANDY CLAY; grey, very stiff.*
13.0'	SP SM	4		NP	98	5	30 38	*SAND-SILTY SAND; light brown, dense, some small gravel.*
	SW SM	3		NP	75	6	28 32	*GRAVELLY SAND-SILTY GRAVELLY SAND; brown, zones of fine white sands, gravel to 3" max., cobbles at 5", caving.*
19.0'		3		NP	68	6	21	*tan, med. dense.*
22.0'	ML	22	38	12	96	70	19 44	*SANDY SILT; light brown and grey, med. dense.*

T.H. 75-15

El.538±

Soil	MC	LL	PI	-4	-200	N	Description
ML	7		NP	94	65	12	*SANDY SILT; light brown, gravel to 1 1/2" max.*
	7		NP	92	62	38	*cemented layers.*
	6		NP	97	67	9	*loose.*
CL	11	32	15	99	62	18 17	*SANDY CLAY; light brown and grey, stiff.*
GP GM	2		NP	51	6	48 9 22	*SANDY GRAVEL-SILTY SANDY GRAVEL; tan, med. dense, gravel to 3" max. some belling.*
SP SM	8		NP	61	5	19	*GRAVELLY SAND-SILTY GRAVELLY SAND; tan, med. dense, gravel to 3" max., some belling.*

T.H. 75-18

El.536±

Depth	Soil	MC	LL	PI	-4	-200	N	Description
1.5'	SC	4	28	14	85	20	17	*GRAVELLY CLAYEY SAND; brown, gravel to 2" max.*
5.0'	CL	11	30	11	98	57	7 20	*SANDY CLAY; tan, med. to very stiff.*
9.0'	SW SM	2		NP	70	6	25 32 27	*GRAVELLY SAND-SILTY GRAVELLY SAND; tan, med. to dense, gravel and cobbles to 4" max.*
13.0'	SP	2		NP	56	3	19 20 19	*GRAVELLY SAND; tan, med. dense, gravel and cobbles to 4" max.*

T.H. 75-19

El.556±

Depth	Soil	MC	LL	PI	-4	-200	N	Description
	CL	12	37	20	100	82	19 32	*SANDY CLAY; brown, very stiff.*
8.0'		14	44	24	100	91	36 45 50	*tan, hard to very hard.*
9.0'	SM	7		NP	100	28	14	*SILTY SAND; tan, med. dense.*
10.0'	[illegible]	2		NP	98	9	15	*SAND-SILTY SAND; tan, med. dense, some small gravel, one 4" cobble, caving.*
13.0'	SP	2		NP	86	4	26 24	*SAND; light tan, med. dense, gravel and cobbles to 4" max.*

T.H. 75-22

El.578±

Depth	Soil	MC	LL	PI	-4	-200	N	Description
2.0'	CL	8	24	8	99	57	34	*SANDY CLAY; brown, hard, some gravel.*
	SC	8	36	19	89	33	80*	*CLAYEY SAND; brown, white cementation, some gravel.*
6.0'		7	28	12	83	22	80* 56	*GRAVELLY CLAYEY SAND; brown, cemented.*
10.0'	SW SC	4	25	8	83	11	28 26	*GRAVELLY SAND-CLAYEY GRAVELLY SAND; brown, med. dense, gravel to 2" max.*
13.0'	SM	3		NP	88	18	18 15	*SILTY SAND; light brown, med. dense, gravel to 2" max.*
17.0'	SW SM	4		NP	80	11	26 26 27	*GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, med. dense, 2" max. gravel, SM lenses.*
19.0'	ML	7		NP	99	53	18	*SANDY SILT; light brown, med dense.*
24.0'	SW SM	2		NP	84	6	28 34	*GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, dense, gravel to 3" max.*

Notes.

1. *TH 75-12 through 75-22 were drilled during January 1975 with a 16-inch diameter bucket-type power auger.*
2. *All holes were drilled in borrow areas not shown on Plan.*
3. *For legend see Plate 25.*

LOGS

5 0 5 10 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE I GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.H. 75-12 THRU T.H. 75-22

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

PLATE B-20

1

2

U.S. ARMY ENGINEER DISTRICT

T.H. 75-23

El. 574±

Depth	Class	MC	LL	PI	-4	-200	N	Description
	CL	9	41	22	100	73	17 35	SANDY CLAY; light brown, hard.
		13	30	13	100	57	22 19 15	tan.
11.0'		12	35	15	100	71	32 27	tan and grey.
	SM	11		NP	97	41	30	SILTY SAND; tan and grey-brown, very dense, very fine sand, gravel to 1 1/2" max.
14.0'		3		NP	77	17	50	SILTY GRAVELLY SAND.
17.0'	SW SM	3		NP	69	8	27 32	GRAVELLY SAND-SILTY GRAVELLY SAND; brown, dense, cobbles to 5" max.
20.0'	SP SM	2		NP	62	6	41 -	

T.H. 75-24

El. 553±

Depth	Class	MC	LL	PI	-4	-200	N	Description
	CL	12	28	13	100	88	5	SANDY CLAY; brown, med. soft.
		11	42	24	99	90	27 25	light brown, hard.
8.0'		17	40	21	100	87	14 22	
9.0'	SM	6		NP	99	27	20	SILTY SAND; light brown, med dense.
12.0'		2		NP	91	8	31 28	SAND-SILTY SAND; light brown, small gravel.
13.5'	ML	4		NP	99	33	27	SANDY SILT; tan, med dense, fine grained.
17.0'	CL	11	43	24	99	85	45 42	SANDY CLAY; tan, hard.
19.0'	SM	4		NP	94	29	39 55	SILTY SAND; light brown, dense, small gravel.
21.0'	ML	10		NP	100	95	60	SANDY SILT; tan, very hard.

T.H. 75-25

El. 550±

Depth	Class	MC	LL	PI	-4	-200	N	Description
3.0'	CL	5	25	11	99	66	17 25	SANDY CLAY; light brown, some small gravel.
5.0'	SM	6		NP	100	39		SILTY SAND; light brown,
8.0'	ML	8		NP	100	78	60 47	SANDY SILT; light tan, s lenses.
	SM	13		NP	99	27	40 42	SILTY SAND; light brown, sand lenses.
13.0'		19		NP	99	45	39 41	light brown-gray, dense.
15.0'	ML	10		NP	99	73	55	SANDY SILT; light tan, c
	SW SM	3		NP	81	7	40 40	GRAVELLY SAND-SILTY GRAV brown, dense, gravel to
21.0'		2		NP	69	6	20 25	tan, med. dense, caving.

T.H. 75-28

El. 520±

Depth	Class	MC	LL	PI	-4	-200	N	Description
	CL	9	25	8	99	71	51	SANDY CLAY; brown, hard, some gravel to 2" max.
3.5'		9	34	17	90	52	35	
5.0'	SW SM	3			70	8	33	GRAVELLY SAND-SILTY GRAVELLY SAND; tan, hard.
	SP	3		NP	95	4	31 41 30	SAND; brown, dense, some gravel to 3" max., CL lense, brown stiff from 5.2 to 5.4 feet.
13.0'		4		NP	54	3	50 41	GRAVELLY SAND; brown, very dense.
W 17.0'	SW	4		NP	83	4	40 48 50	GRAVELLY SAND; brown, dense, some gravel and cobbles to 4" max.
19.0'				NP	77	4	43	brown, coarse, gravel to 2" max., caving due to water.

T.H. 75-29

El. 518±

Depth	Class	MC	LL	PI	-4	-200	N	Description
1.0'	CL	9	27	10	98	65	27	SANDY CLAY; brown, med. dense.
	SW SM	5		NP	58	11	42	GRAVELLY SAND-SILTY GRAVELLY SAND; brown, dense, gravel to 2" max.
6.0'		3		NP	88	5	44 47	SAND-SILTY SAND; light brown, gravel to 1 1/2" max.
10.0'	SP	5		NP	88	4	32 32	SAND; light brown, dense, gravel to 1 1/2" max., three 4" cobbles.
10.3'	CL	33	46	20	100	81	30	SANDY CLAY; grey with brown streaks, stiff.
14.0'	SP	6		NP	89	4	39 60+	SAND; light brown, thin CH lense, gravel to 3" max.
16.0'	SM	18		NP	83	13	32 60+	SILTY GRAVELLY SAND, light brown and gray, dense, gravel and cobbles to 5" max.
W 17.5' 18.0'	SP	16		NP	83	3		GRAVELLY SAND; gray, dense, gravel to 2" max., several cobbles to 5" max.

T.H. 75-30

El. 504±

Depth	Class	MC	LL	PI	-4	-200	N	Description
3.0'	ML	8		NP	96	61		SANDY SILT; brown, very 4" cobbles.
4.0'	CL	5	27	9	85	46		GRAVELLY SANDY CLAY, lig to 2 1/2" max.
6.0'	ML	5		NP	96	65		SANDY SILT; light brown.
	CL	17	37	17	100	77		SANDY CLAY, brown, two 3
13.0'		20	39	19	100	78		stiff, some gravel.
15.5'	SW SM	7		NP	61	11		GRAVELLY SAND-SILTY GRAV brown, gravel and severa 4" max., caving below 15
W 15.5' 18.0'	SP SM	-		NP	61	6		

T.H. 75-33

El. 475±

Depth	Class	MC	LL	PI	-4	-200	N	Description
5.0'	CH	43	68	39	100	99	6 6	FAT CLAY; gray with rust colored streaks, med.
6.0'	SC	13	31	18	97	48		CLAYEY SAND; light brown, stiff, some gravel.
9.0'	SW SM			NP	96	9	23	SAND-SILTY SAND; grey, med. dense to dense, gravel to 1 1/2" max.
W 10.5'	SM			NP	98	30	51	SILTY SAND; grey, very dense, fine grained.
15.0'	SP SM			NP	96	11	15 7 3	SAND-SILTY SAND; grey, med. dense, gravel to 1 1/2" max.
20.0'	SP			NP	82	3	5 8 4	GRAVELLY SAND; grey, loose, gravel to 1" max.
23.0'	SP SM			NP	97	6	7 5	SAND-SILTY SAND; grey, loose, some gravel to 1" max.
27.0'	SW SM			NP	99	6	18 12 11	SAND-SILTY SAND; grey, med. dense, gravel to 1" max.
29.5'	SP			NP	95	3	3 3	SAND; grey, loose, coarse grainee.
31.0'	CL		45	20	100	72	2	SANDY CLAY; grey, soft.
37.0'	SP SM			NP	93	12	2 3 2	SAND-SILTY SAND; dark grey, very loose ML and SM lenses, some gravel.
40.0'	SW SM			NP	83	5		GRAVELLY SAND-SILTY GRAVELLY SAND; grey, dense, gravel to 1" max., a few 5" cobbles.
43.0'	SP			NP	96	4		SAND; grey, dense, gravel to 1" max.
46.0'	SP SM			NP	99	6		SAND-SILTY SAND; grey, dense, fine grained, some brown CL lenses.
48.5'	ML			NP	100	56		SANDY SILT; grey, stiff.
53.0'	SP SM			NP	94	6		SAND-SILTY SAND; grey, gravel and cobbles to 6" max.
60.0'	SW			NP	87	4		SAND- grey, gravel and cobbles to 6" max.

T.H. 75-34

El. 475±

Depth	Class	MC	LL	PI	-4	-200	N	Description
4.0'	CH	39	69	38	100	100	9	FAT CLAY, gray to brown, stiff.
	SM	15		NP	94	31	7	SILTY SAND; brown, loose, some gravel to 1" max.
W 9.0' 10.0'		8		NP	97	25	56	grey, dense, small gravel.
	SW			NP	99	11	16 12 7 9	SAND-SILTY SAND; grey, med. dense, some brown clay lenses, gravel to 2" max., three 4" cobbles.
20.0'	SM			NP	96	5	4 2 4	very loose.
25.5'	SP			NP	97	4	3 2 3 8	SAND; grey, very loose, gravel to 2" max.
26.5'	SM			NP	98	26	5	SILTY SAND; black, soft.
29.0'	SP			NP	89	2	5	SAND; grey, loose, coarse, gravel to 2" max.
30.0'	ML			NP	98	78	5	SANDY SILT; blue-grey and brown.
	SW SM			NP	94	10	20 23	SAND-SILTY SAND; grey, med. dense, gravel to 2" max., some 4" cobbles.
38.0'				NP	80	5	26 16	GRAVELLY SAND-SILTY GRAVELLY SAND; grey, med. dense some 4" cobbles.
	SP			NP	90	3		SAND; grey, med. dense, cobbles to 5" max., cobble layer at 42 feet.
45.0'				NP	76	1		GRAVELLY SAND; grey.

T.H. 75-35

El. 548±

Depth	Class	MC	LL	PI	-4	-200	N	Description
2.5'	SC	8	29	12	97	47	8	CLAYEY SAND, light brow gravel to 1" max.
6.0'	SM	6		NP	85	15	15 13 22	SILTY GRAVELLY SAND, lig dense, gravel to 1 1/2"
10.0'	SW SM	4		NP	95	6	30 20	SAND-SILTY SAND, light b med. dense.
11.0'	SM	13		NP	99	30	22	SILTY SAND, tan, med. de
14.0'	SW SM	5		NP	88	11	47 58	SAND-SILTY SAND, tan, de dense, gravel to 1 1/2"
16.0'	SP	2		NP	67	3	54	GRAVELLY SAND, tan to li very dense to med. dense 2 1/2" max.
	SW	2		NP	83	2	25 43	
21.0'		2		NP	62	4	32 16	
24.0'	GW	2		NP	48	4	60+	SANDY GRAVEL, tan, very and cobbles to 4" max
28.0'	SW	3		NP	91	2	60 60+	SAND, tan and gray, very gravel and cobbles to 4"
30.0'	SM	2		NP	93	14	60+ 56	SILTY SAND; tan and gray ML lense at 29.5 feet.
31.5'	CL	25	41	21	99	72	15	SANDY CLAY; light brown, some SM streaks.
33.0'	SW SM	8		NP	84	11	60+	GRAVELLY SAND-SILTY GRAV several ML streaks, grav
36.0'	SP	3		NP	75	2	60+ 58	GRAVELLY SAND, tan and g gravel to 2 1/2" max

LOGS

VERT. SCALE 5 0 5 10 FEET

T.H. 75-25

LL	PI	-4	-200	N	Description
25	11	99	66	17 25	SANDY CLAY; light brown, very stiff, some small gravel.
	NP	100	39		SILTY SAND; light brown, dense.
	NP	100	78	60 47	SANDY SILT; light tan, some cemented lenses.
	NP	99	27	40 42	SILTY SAND; light brown, dense, some sand lenses.
	NP	99	45	39	light brown-grey, dense.
	NP	99	73	41 55	SANDY SILT; light tan, cemented lenses.
	NP	81	7	40 40	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, dense, gravel to 1 1/2" max.
	NP	69	6	20 25	tan, med. dense, caving.

T.H. 75-26

El.546±

Depth		MC	LL	PI	-4	-200	N	Description
2.0'	ML	6		NP	100	75	8	SANDY SILT; light brown, soft.
	CL	10	30	14	100	80	30 40	SANDY CLAY; brown, hard.
7.0'		10	31	15	100	59	39 17	light brown, med. to dense.
11.0'	SM	6		NP	100	41	22 24	SILTY SAND; light brown, med. dense.
12.5'	ML	8		NP	100	52	14	SANDY SILT; tan, very fine sand.
14.0'	SM	7		NP	99	26	60	SILTY SAND; tan, rust colored, cemented layers.
17.0'	SW SM	4		NP	71	8	38 38	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, dense, gravel to 2" max.
21.0'	SP	3		NP	57	4	25 26 27	GRAVELLY SAND; brown, gravel to 3" max.

T.H. 75-27

El.544±

Depth		MC	LL	PI	-4	-200	N	Description
2.0'	CL	9	31	14	100	74	60	SANDY CLAY; brown, very hard.
5.0'	SC	5	25	11	99	33	57 55	CLAYEY SAND; light brown, very hard, some small gravel.
	CL	11	33	12	100	81	60+ 60+	SANDY CLAY; light tan, cemented.
11.0'		10	40	15	100	95	60+ 60+	light green-grey, very hard, very fine sand, gravel from 10 to 11 feet.
14.0'	SM	3		NP	95	16	50 60+	SILTY SAND; light brown and rust, very dense, some sandstone lenses.
16.0'	ML	8		NP	98	83	60+ 45	SANDY SILT; light brown, very hard lenses.
18.0'	SW SM	2		NP	79	6	27 16	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, med. dense, gravel to 3" max.

T.H. 75-30

LL	PI	-4	-200	N	Description
	NP	96	61		SANDY SILT; brown, very stiff, two 4" cobbles.
27	9	85	46		GRAVELLY SANDY CLAY; light brown, gravel to 2 1/2" max.
	NP	98	65		SANDY SILT; light brown.
37	17	100	77		SANDY CLAY, brown, two 3" cobbles.
39	19	100	78		stiff, some gravel.
	NP	61	11		GRAVELLY SAND-SILTY GRAVELLY SAND; dense, brown, gravel and several cobbles to 4" max., caving below 15 feet.
	NP	61	6		

T.H. 75-31

El.475±

Depth		MC	LL	PI	-4	-200	N	Description
	CH	37	66	39	100	100	5	FAT CLAY; grey to brown-grey, soft.
5.0'		46	64	42	100	100	6	
W8.5'	SM	18		NP	97	35	6	SILTY SAND; brown to brown-grey, soft and loose, scattered gravel with four cobbles to 6" max. at 13 feet to 18 feet depth, some clay lenses.
		-		NP	97	17	6 4	
		-		NP	96	18	6 9 9 7	
23.0'		-		NP	97	13	7 11 12	
	SW	-		NP	99	6	11 13 13	SAND-SILTY SAND; grey, med. dense, some gravel.
33.0'	SM	-		NP	96	7	16 12 9 12	
39.0'	SP	-		NP	98	4	5 9	SAND, grey, loose, clay and gravel layers.
43.0'	ML			NP	100	78		SANDY SILT; grey, stiff, fine sand.
47.0'	SW SM			NP	85	7		GRAVELLY SAND-SILTY GRAVELLY SAND; grey, coarse, gravel, several 4" cobbles.
50.0'	ML			NP	100	75		SANDY SILT; grey, stiff, fine sand.
58.0'	SW SM			NP	89	5		SAND-SILTY SAND; grey coarse, gravel, several 4" cobbles.

T.H. 75-32

El.475±

Depth		MC	LL	PI	-4	-200	N	Description
5.5'	CH	42	68	40	100	96	7 7	FAT CLAY; grey-brown, med. stiff.
W8.5'	SW	11		NP	93	9	23 26	SAND-SILTY SAND; gray-brown, gravel to 2" max., two 6" cobbles, layers of silt.
15.0'	SM			NP	96	12	26 17 32 20	
17.0'	SM			NP	98	22	9	SILTY SAND; grey, med. grained.
22.0'	SW			NP	98	3	7 5 6	SAND; grey, loose, gravel to 1" max.
27.0'	SP SM			NP	100	6	7 12 7 6	SAND-SILTY SAND; gray, loose to med. dense, gravel to 1" max.
	SP			NP	100	4	11	SAND; gray, loose to med. dense, gravel to 1" max.
32.0'				NP	60	3	7 16	GRAVELLY SAND; gray, loose to med. dense.
36.0'	SP SM			NP	93	6	23 29 22	SAND-SILTY SAND; grey, med. dense, gravel to 1" max.
39.0'	SP			NP	88	4		SAND; grey, med. dense, some gravel.
45.0'	ML			NP	75	65		SANDY GRAVELLY SILT; gray, stiff, some gravel.
50.0'	SW SM			NP	90	5		SAND-SILTY SAND; grey, dense, some gravel and several cobbles to 5" max.
52.0'	ML			NP	92	53		SANDY SILT; grey, stiff, some gravel.
56.0'	SP SM			NP	90	6		SAND-SILTY SAND; gray, dense, several cobbles to 7" max.

T.H. 75-35

LL	PI	-4	-200	N	Description
29	12	97	47	9 15	CLAYEY SAND, light brown, stiff, some gravel to 1" max.
	NP	85	15	13 22	SILTY GRAVELLY SAND; light brown, med. dense, gravel to 1 1/2" max.
	NP	95	6	30 20	SAND-SILTY SAND; light brown to tan, med. dense.
	NP	99	30	22	SILTY SAND; tan, med. dense.
	NP	88	11	47 58	SAND-SILTY SAND; tan, dense to very dense, gravel to 1 1/2" max.
	NP	67	3	54	GRAVELLY SAND; tan to light brown, very dense to med. dense, gravel to 2 1/2" max.
	NP	83	2	25 43	
	NP	62	4	32 16	
	NP	48	4	60+	SANDY GRAVEL, tan, very dense, gravel and cobbles to 4" max.
	NP	91	2	60 60+	SAND; tan and gray, very dense, some gravel and cobbles to 4" max.
	NP	93	14	60+ 56	SILTY SAND; tan and gray, very dense, ML lense at 29.5 feet.
41	21	99	72	15	SANDY CLAY; light brown, very stiff, some SM streaks.
	NP	84	11	60+	GRAVELLY SAND-SILTY GRAVELLY SAND; tan, several ML streaks, gravel and two 4" cobbles.
	NP	75	2	60+ 58	GRAVELLY SAND; tan and gray, very dense, gravel to 2 1/2" max.

5 10 FEET

Notes:

1. TH-75-23 through 75-35 were drilled during January 1975 with a 16-inch diameter bucket-type power auger.
2. For locations of test holes 75-31 through 75-34 see Plate 18. All other holes were drilled in borrow areas.
3. For legend see Plate 25.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.H.75-23 THRU T.H.75-35

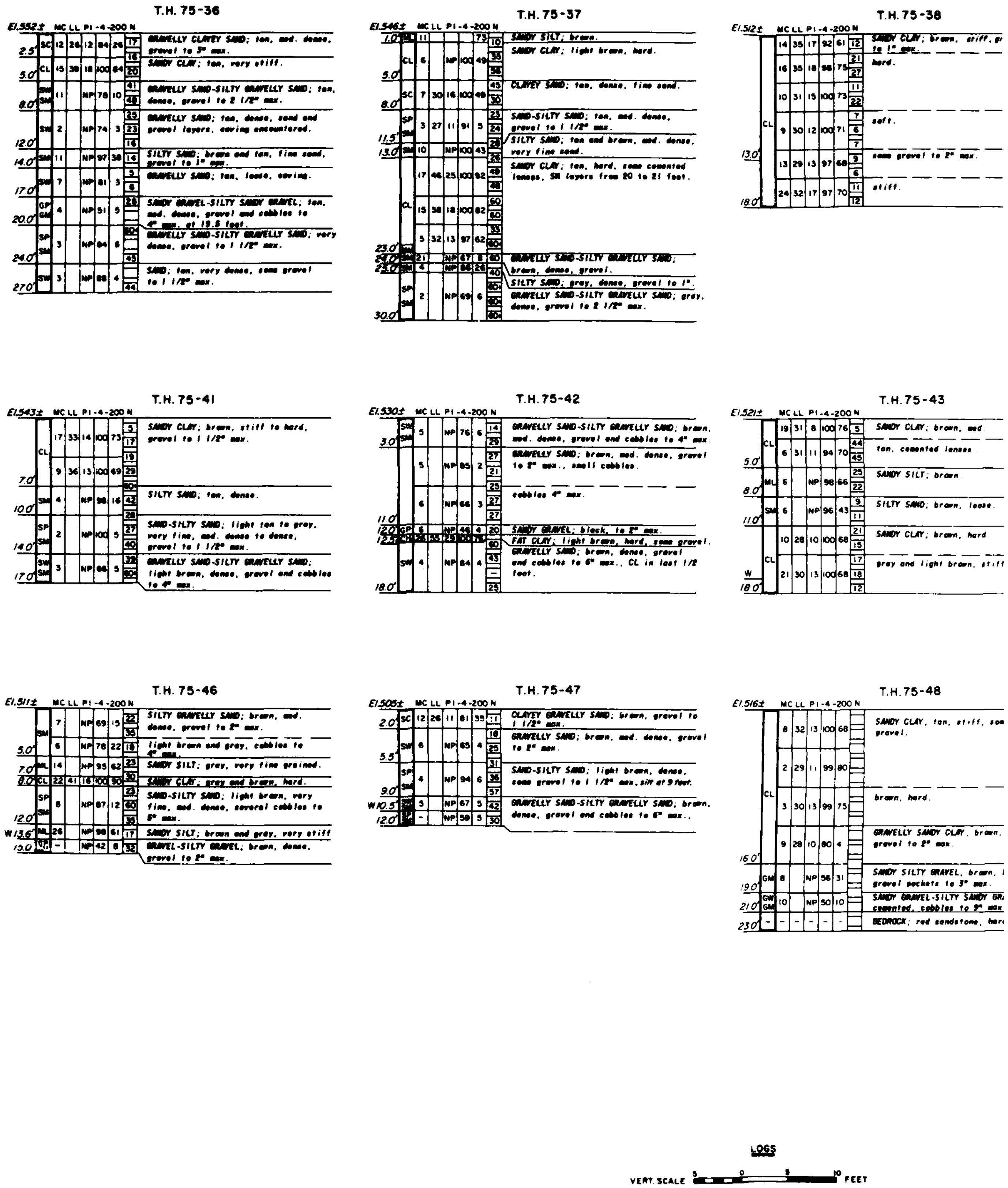
SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____-B-____

DISTRICT FILE NO.

U.S. ARMY ENGINEER DISTRICT



T.H. 75-36

El.552±		MC	LL	PI	-4	-200	N	
2.5'	SC	12	26	12	84	26	17 16	GRAVELLY CLAYEY SAND; tan, med. dense, gravel to 3" max.
5.0'	CL	15	38	18	100	84	20	SANDY CLAY; tan, very stiff.
8.0'	SW SM	11		NP	78	10	41 48	GRAVELLY SAND-SILTY GRAVELLY SAND; tan, dense, gravel to 2 1/2" max.
12.0'	SW	2		NP	74	3	25 23 16	GRAVELLY SAND; tan, dense, sand and gravel layers, caving encountered.
14.0'	SM	11		NP	97	38	14	SILTY SAND; brown and tan, fine sand, gravel to 1" max.
17.0'	SW	7		NP	81	3	5 6	GRAVELLY SAND; tan, loose, caving.
20.0'	GP GM	4		NP	51	5	28	SANDY GRAVEL-SILTY SANDY GRAVEL; tan, med. dense, gravel and cobbles to 4" max. at 19.5 feet.
24.0'	SP SM	3		NP	84	6	80+ 45	GRAVELLY SAND-SILTY GRAVELLY SAND; very dense, gravel to 1 1/2" max.
27.0'	SW	3		NP	88	4	44	SAND; tan, very dense, some gravel to 1 1/2" max.

T.H. 75-37

El.546±		MC	LL	PI	-4	-200	N	
1.0'	ML	11				73	10	SANDY SILT; brown.
5.0'	CL	6		NP	100	49	35 56	SANDY CLAY; light brown, hard.
8.0'	SC	7	30	16	100	49	45 30	CLAYEY SAND; tan, dense, fine sand.
11.5'	SP SM	3	27	11	91	5	23 24	SAND-SILTY SAND; tan, med. dense, gravel to 1 1/2" max.
13.0'	SM	10		NP	100	43	28 26	SILTY SAND; tan and brown, med. dense, very fine sand.
	CL	17	46	25	100	92	49 48	SANDY CLAY; tan, hard, some cemented lenses, SM layers from 20 to 21 feet.
		15	38	18	100	82	60 60	
23.0'		5	32	13	97	62	33 80+	
24.0'	SW SM	21		NP	67	8	80	GRAVELLY SAND-SILTY GRAVELLY SAND; brown, dense, gravel.
25.0'	SM	4		NP	86	26	40	SILTY SAND; grey, dense, gravel to 1".
30.0'	SP SM	2		NP	69	6	80+ 80+ 80+	GRAVELLY SAND-SILTY GRAVELLY SAND; grey, dense, gravel to 2 1/2" max.

T.H. 75-38

El.512±		MC	LL	PI	-4	-200	N	
	CL	14	35	17	92	61	12	SANDY CLAY; brown, stiff, gr to 1" max.
		16	35	18	98	75	21 27	hard.
		10	31	15	100	73	11 22	
		9	30	12	100	71	7 6 7	soft.
13.0'		13	29	13	97	68	9 6	some gravel to 2" max.
18.0'		24	32	17	97	70	11 12	stiff.

T.H. 75-41

El.543±		MC	LL	PI	-4	-200	N	
	CL	17	33	14	100	73	5 17	SANDY CLAY; brown, stiff to hard, gravel to 1 1/2" max.
7.0'		9	36	13	100	69	19 29	
10.0'	SM	4		NP	98	16	80+ 42	SILTY SAND; tan, dense.
14.0'	SP SM	2		NP	100	5	28 27 40	SAND-SILTY SAND; light tan to grey, very fine, med. dense to dense, gravel to 1 1/2" max.
17.0'	SW SM	3		NP	86	5	32 80+	GRAVELLY SAND-SILTY GRAVELLY SAND; light brown, dense, gravel and cobbles to 4" max.

T.H. 75-42

El.530±		MC	LL	PI	-4	-200	N	
3.0'	SW SM	5		NP	76	6	14 29	GRAVELLY SAND-SILTY GRAVELLY SAND; brown, med. dense, gravel and cobbles to 4" max.
		5		NP	85	2	27 21	GRAVELLY SAND; brown, med. dense, gravel to 2" max., small cobbles.
11.0'		6		NP	66	3	25 27 27	cobbles 4" max.
12.0'	GP	6		NP	46	4	20	SANDY GRAVEL; black, to 2" max.
12.5'	CH	26	55	29	100	78	60	FAT CLAY; light brown, hard, some gravel.
18.0'	SW	4		NP	84	4	43 – 25	GRAVELLY SAND; brown, dense, gravel and cobbles to 6" max., CL in last 1/2 foot.

T.H. 75-43

El.521±		MC	LL	PI	-4	-200	N	
	CL	19	31	8	100	76	5	SANDY CLAY; brown, med.
5.0'		6	31	11	94	70	44 45	tan, cemented lenses.
8.0'	ML	6		NP	98	66	25 22	SANDY SILT; brown.
11.0'	SM	6		NP	96	43	9 11	SILTY SAND; brown, loose.
	CL	10	28	10	100	68	21 15	SANDY CLAY; brown, hard.
W 18.0'		21	30	13	100	68	17 18 12	gray and light brown, stiff

T.H. 75-46

El.511±		MC	LL	PI	-4	-200	N	
	SM	7		NP	69	15	22 36	SILTY GRAVELLY SAND; brown, med. dense, gravel to 2" max.
5.0'		6		NP	78	22	18	light brown and grey, cobbles to 4" max.
7.0'	ML	14		NP	95	62	23	SANDY SILT; grey, very fine grained.
8.0'	CL	22	41	16	100	90	30	SANDY CLAY; grey and brown, hard.
12.0'	SP SM	8		NP	87	12	23 60 35	SAND-SILTY SAND; light brown, very fine, med. dense, several cobbles to 5" max.
W 13.6'	ML	26		NP	98	61	17	SANDY SILT; brown and grey, very stiff
15.0'	GP GM	–		NP	42	8	32	GRAVEL-SILTY GRAVEL; brown, dense, gravel to 2" max.

T.H. 75-47

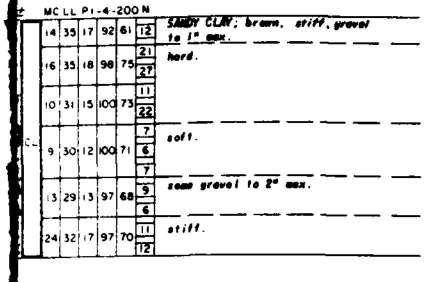
El.505±		MC	LL	PI	-4	-200	N	
2.0'	SC	12	26	11	81	35	11	CLAYEY GRAVELLY SAND; brown, gravel to 1 1/2" max.
5.5'	SW	6		NP	65	4	18 25	GRAVELLY SAND; brown, med. dense, gravel to 2" max.
9.0'	SP SM	4		NP	94	6	31 36 57	SAND-SILTY SAND; light brown, dense, some gravel to 1 1/2" max., silt at 9 feet.
W 10.5'	SW SM	5		NP	67	5	42	GRAVELLY SAND-SILTY GRAVELLY SAND; brown, dense, gravel and cobbles to 6" max.,
12.0'	SP SM	–		NP	59	5	30	

T.H. 75-48

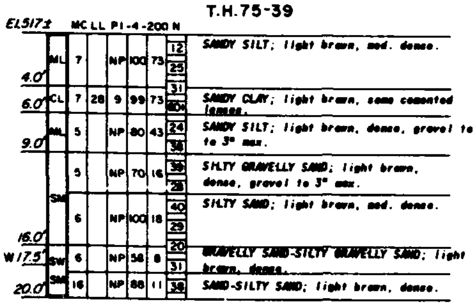
El.516±		MC	LL	PI	-4	-200	N	
	CL	8	32	13	100	68		SANDY CLAY, tan, stiff, som gravel.
		2	29	11	99	80		
		3	30	13	99	75		brown, hard.
16.0'		9	28	10	80	4		GRAVELLY SANDY CLAY, brown, gravel to 2" max.
19.0'	GM	8		NP	56	31		SANDY SILTY GRAVEL, brown, gravel pockets to 3" max.
21.0'	GW GM	10		NP	50	10		SANDY GRAVEL-SILTY SANDY GR cemented, cobbles to 9" max
23.0'	–	–	–	–	–	–		BEDROCK; red sandstone, har

LOGS

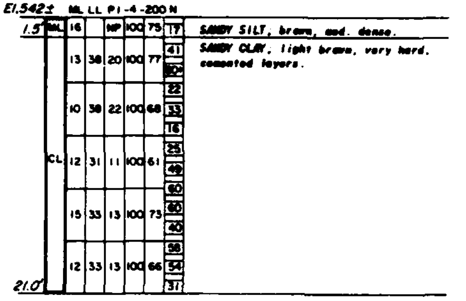
T.H. 75-38



T.H. 75-39



T.H. 75-40



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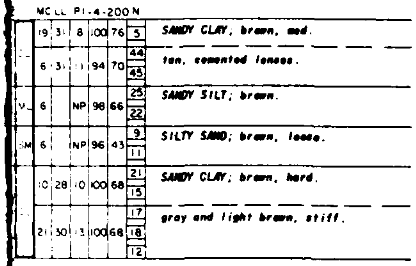

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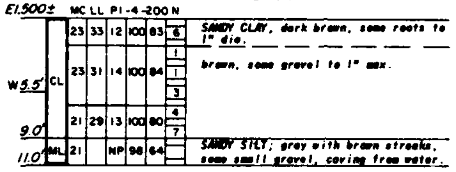

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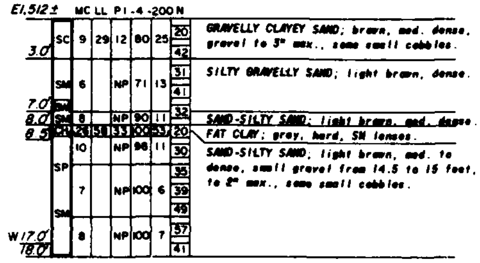
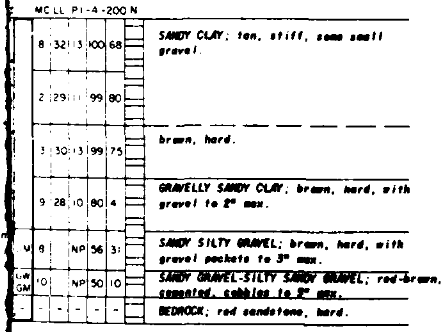


T.H. 75-48



Notes:

1. *TH 75-36 through 75-48 were drilled during February 1975 with a 16-inch diameter bucket-type power auger.*
2. *All holes were drilled in borrow areas not shown on Plan.*
3. *For legend see Plate 25.*

5 10 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE I GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.H. 75-36 THRU T.H. 75-48

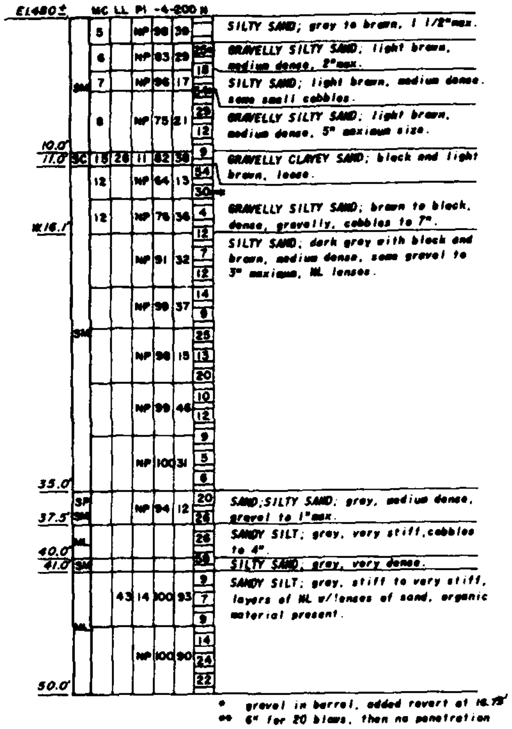
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

1

2

U.S. ARMY ENGINEER DISTRICT

T.H. 75-49



SILTY SAND; grey to brown, 1 1/2"max.

GRAVELLY SILTY SAND; light brown, medium dense, 2"max.

SILTY SAND; light brown, medium dense, some small cobbles.

GRAVELLY SILTY SAND; light brown, medium dense, 5" maximum size.

GRAVELLY CLAYEY SAND; black and light brown, loose.

GRAVELLY SILTY SAND; brown to black, dense, gravelly, cobbles to 7".

SILTY SAND; dark grey with black and brown, medium dense, some gravel to 3" maximum, ML lenses.

SAND;SILTY SAND; grey, medium dense, gravel to 1"max.

SANDY SILT; grey, very stiff, cobbles to 4".

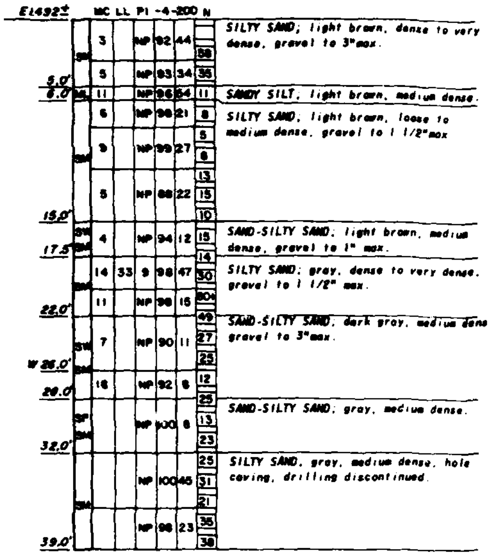
SILTY SAND; grey, very dense.

SANDY SILT; grey, stiff to very stiff, layers of ML w/lenses of sand, organic material present.

* gravel in barrel, added revert at 16.75'

** 6" for 20 blows, then no penetration

T.H. 75-50



SILTY SAND; light brown, dense to very dense, gravel to 3"max.

SANDY SILT; light brown, medium dense.

SILTY SAND; light brown, loose to medium dense, gravel to 1 1/2"max

SAND-SILTY SAND; light brown, medium dense, gravel to 1" max.

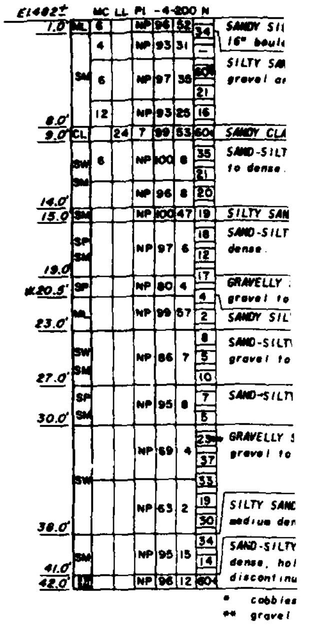
SILTY SAND; gray, dense to very dense, gravel to 1 1/2" max.

SAND-SILTY SAND; dark gray, medium dense, gravel to 3"max.

SAND-SILTY SAND; gray, medium dense.

SILTY SAND, gray, medium dense, hole caving, drilling discontinued.

T.H. 75.51



SANDY SI
16" boul

SILTY SA
gravel a

SANDY CLA

SAND-SILT
to dense.

SILTY SAN

SAND-SILT
dense.

GRAVELLY
gravel to

SANDY SIL

SAND-SILT
gravel to

SAND-SILT

GRAVELLY
gravel to

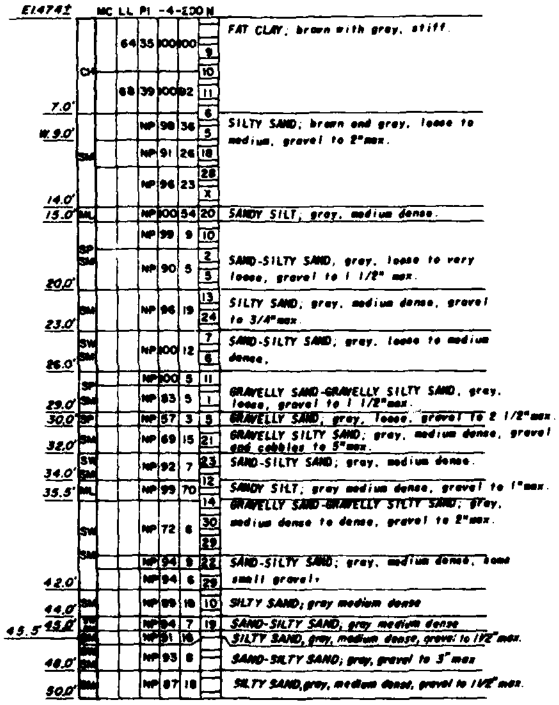
SILTY SAN
medium den

SAND-SILTY
dense, hol
discontinu

* cobbles

** gravel

T.H. 75-53



FAT CLAY; brown with grey, stiff.

SILTY SAND; brown and grey, loose to medium, gravel to 2"max.

SANDY SILT; grey, medium dense.

SAND-SILTY SAND, grey, loose to very loose, gravel to 1 1/2" max.

SILTY SAND; grey, medium dense, gravel to 3/4"max.

SAND-SILTY SAND; grey, loose to medium dense,

GRAVELLY SAND-GRAVELLY SILTY SAND, grey, loose, gravel to 1 1/2"max.

GRAVELLY SAND, grey, loose, gravel to 2 1/2"max.

GRAVELLY SILTY SAND; grey, medium dense, gravel and cobbles to 5"max.

SAND-SILTY SAND; grey, medium dense.

SANDY SILT; grey medium dense, gravel to 1"max.

GRAVELLY SAND-GRAVELLY SILTY SAND; grey, medium dense to dense, gravel to 2"max.

SAND-SILTY SAND; grey, medium dense, some small gravel.

SILTY SAND; grey medium dense

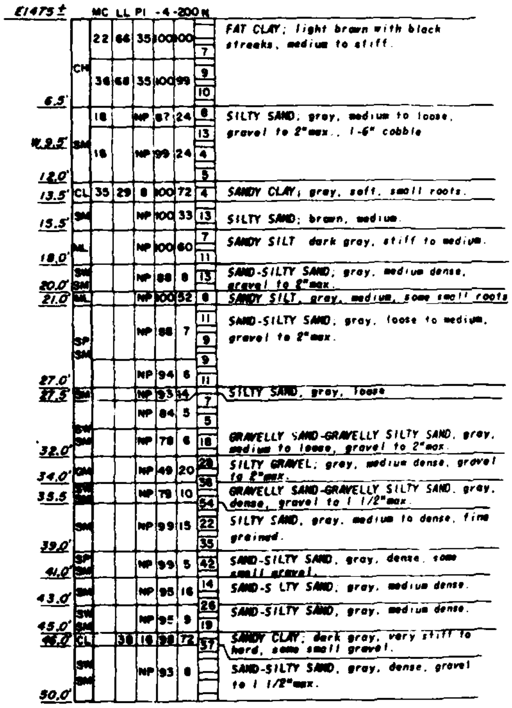
SAND-SILTY SAND, grey medium dense

SILTY SAND, grey, medium dense, gravel to 1 1/2"max.

SAND-SILTY SAND; grey, gravel to 3" max

SILTY SAND, grey, medium dense, gravel to 1 1/2"max.

T.H. 75-54



FAT CLAY; light brown with black streaks, medium to stiff.

SILTY SAND; gray, medium to loose, gravel to 2"max., 1-6" cobble

SANDY CLAY; grey, soft, small roots.

SILTY SAND; brown, medium.

SANDY SILT dark gray, stiff to medium.

SAND-SILTY SAND; gray, medium dense, gravel to 2"max.

SANDY SILT, gray, medium, some small roots.

SAND-SILTY SAND; gray, loose to medium, gravel to 2"max.

SILTY SAND, gray, loose

GRAVELLY SAND-GRAVELLY SILTY SAND, gray, medium to loose, gravel to 2"max.

SILTY GRAVEL; grey, medium dense, gravel to 2"max.

GRAVELLY SAND-GRAVELLY SILTY SAND, gray, dense, gravel to 1 1/2"max.

SILTY SAND, gray, medium to dense, fine grained.

SAND-SILTY SAND, gray, dense, some small gravel.

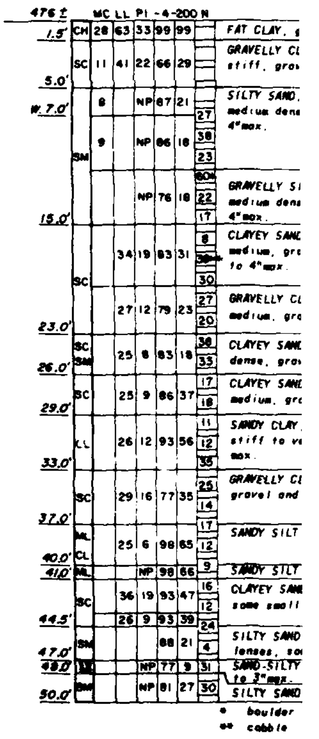
SAND-SILTY SAND, gray, medium dense.

SAND-SILTY SAND, gray, medium dense.

SANDY CLAY; dark gray, very stiff to hard, some small gravel.

SAND-SILTY SAND, gray, dense, gravel to 1 1/2"max.

T.H. 75-55



FAT CLAY,

GRAVELLY CL
stiff, gra

SILTY SAND,
medium dens
4"max.

GRAVELLY SI
medium dens
4"max.

CLAYEY SAN
medium, gr
to 4"max.

GRAVELLY CL
medium, gr

CLAYEY SAN
dense, gra

CLAYEY SAN
medium, gr

SANDY CLAY,
stiff to v
max.

GRAVELLY CL
gravel and

SANDY SILT

SANDY SILT

CLAYEY SAN
some small

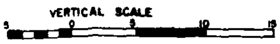
SILTY SAND
lenses, so

SAND-SILTY
to 3"max.

SILTY SAND

* boulder

** cobble



CORPS OF ENGINEERS

T.H. 75.51

El482±

Depth		MC	LL	PI	-4	-200	N	Description
1.0'	ML	6		NP	96	52	34	SANDY SILT; gray to brown, very stiff, 18" boulder at 6".
	SM	4		NP	93	31	—	
		6		NP	97	36	80* 21	SILTY SAND, brown, medium dense, gravel and cobbles to 4"max.
8.0'		12		NP	93	25	16	
9.0'	CL		24	7	99	53	60*	SANDY CLAY; black very hard, plastic.
	SW-SM	6		NP	100	8	35 21	SAND-SILTY SAND; brown, medium dense to dense.
14.0'				NP	96	8	20	
15.0'	SM			NP	100	47	19	SILTY SAND; gray and brown, medium dense.
19.0'	SP-SM			NP	97	6	18 12 17	SAND-SILTY SAND; light brown, medium dense.
W20.5'	SP			NP	80	4	4	GRAVELLY SAND; light brown, medium dense, gravel to 2 1/2" max.
23.0'	ML			NP	99	57	2	SANDY SILT; gray, soft, some roots.
27.0'	SW-SM			NP	86	7	8 5 10	SAND-SILTY SAND; light brown, loose, gravel to 3"max., ML lense at 27'.
30.0'	SP-SM			NP	95	8	7 5	SAND-SILTY SAND; brown, loose.
	SW			NP	69	4	23** 37 33	GRAVELLY SAND; gray, medium to dense, gravel to 1 1/2"max.
38.0'				NP	63	2	19 30	SILTY SAND, light brown, dense to medium dense.
41.0'	SM			NP	95	15	34 14	SAND-SILTY SAND; light brown, very dense, hole caved, drilling discontinued.
42.0'	ML			NP	96	12	60*	

* cobbles
** gravel in shoe

T.H. 75-52

El475±

Depth		MC	LL	PI	-4	-200	N	Description
	CH		62	31	100	98	 14 11	FAT CLAY; light brown, and gray, stiff.
8.0'			62	34	100	98	10 8	
	SM			NP	96	27	17	SILTY SAND; gray and brown, medium dense, gravel to 1 1/2"max.
W10.5'				NP	96	22	44*	
14.0'				NP	97	16	25** 9	
18.0'	SW-SM			NP	92	8	13 2 4	SAND-SILTY SAND; gray and light brown, medium to very loose, gravel to 1"max.
22.0'	SW			NP	98	4	15 14	SAND; gray and light brown, medium dense, gravel to 1"max.
22.5'	SM			NP	91	46	2	SILTY SAND, gray, very loose, gravel to 1"max.
	SW			NP	78	3	4	
28.0'				NP	68	2	5 6	GRAVELLY SAND; light brown, loose gravel to 3"max.
	SM			NP	87	13	9 10	SILTY SAND; gray, loose.
32.0'				NP	79	21	4	GRAVELLY SILTY SAND; grey, loose, gravel to 1 1/2"max., some 4" cobbles
36.0'	SW			NP	74	4	28 21 21	GRAVELLY SAND; gray, medium dense, gravel and cobbles to 4"max.
37.5'	SM			NP	79	15	11	GRAVELLY SILTY SAND; gray, medium dense,
39.5'	SW			NP	82	3	23	GRAVELLY SAND; gray, medium dense, gravel to 2", one 7" cobble.
41.0'	SM			NP	91	41	20*	SILTY SAND; gray, medium dense, gravel and cobbles to 7"max.
	SM			NP	77	15	14 5	GRAVELLY SILTY SAND; grey, loose, small gravel.
47.0'				NP	87	15	30 45	SILTY SAND; gray, dense to very dense, gravel to 2"max.
50.0'	SW-SM			NP	98	12	27 23	SAND-SILTY SAND; gray, medium dense, hole caved, drilling discontinued.

* cobble
** boulder

T.H. 75-55

476±

Depth		MC	LL	PI	-4	-200	N	Description
1.5'	CH	28	63	33	99	99		FAT CLAY; grey-brown, stiff.
5.0'	SC	11	41	22	66	29		GRAVELLY CLAYEY SAND; dark gray, very stiff, gravel to 3"max.
W7.0'	SM	6		NP	87	21		SILTY SAND, light brown, dense to medium dense, gravel and cobbles to 4"max.
		9		NP	86	18	27 38 23	
15.0'				NP	76	18	80* 22 17	GRAVELLY SILTY SAND; light brown, medium dense, gravel and cobbles to 4"max.
	SC		34	19	83	31	8 30** 30	CLAYEY SAND; light brown, loose to medium, gravel to 1 1/2"max., cobbles to 4"max.
23.0'			27	12	79	23	27 20	GRAVELLY CLAYEY SAND; light brown, medium, graveleand cobbles to 4"max.
26.0'	SC-SM		25	8	83	18	36 33	CLAYEY SAND-SILTY SAND; light brown, dense, gravel to 2"max.
29.0'	SC		25	9	86	37	17 18	CLAYEY SAND, light brown with gray, medium, gravel to 1 1/2"max.
33.0'	CL		26	12	93	56	11 12 35	SANDY CLAY; dark grey to light brown, stiff to very stiff, gravel to 1 1/2" max.
37.0'	SC		29	16	77	35	25 14	GRAVELLY CLAYEY SAND; brown, medium, gravel and cobbles to 4"max.
40.0'	ML-CL		25	6	98	65	17 12	SANDY SILT-SANDY CLAY; brown, stiff.
41.0'	ML			NP	98	66	9	SANDY SILT; dark gray, medium stiff.
	SC		36	19	93	47	16 12	CLAYEY SAND; brown, medium to loose, some small gravel.
44.5'			26	9	93	39	24	
47.0'	SM				88	21	4	SILTY SAND; grey very loose, clay lenses, some small gravel.
48.0'	[illegible]			NP	77	9	31	SAND-SILTY SAND; grey, dense, gravel to 3"max.
50.0'	SM			NP	81	27	30	SILTY SAND; gray, dense, gravel to 3"max

* boulder
** cobble

TICAL SCALE
5 10 15

NOTES:

1. For location of test holes see plate 18.
2. For legend see plate 25.
3. TH 75-49 through 55 were drilled during September-October 1975 with a 16-inch diameter bucket-type power auger.
4. All holes drilled to desired depth except when indicated.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.H. 75-49 THRU T.H. 75-55

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-32

1

2

U.S. ARMY ENGINEER DISTRICT

T.H. 75-60

EL.510±

Depth		MC	LL	PI	-4	-200	N	
	SM	7	•	NP	82	23	30	GRAVELLY SILTY SAND; light brown, medium dense, gravel to 1"max.
17.0'	SM	14 9 14 10	• • •	NP NP NP NP	99 94 85 90	41 21 30 25	28 38 37 34	SILTY SAND; light brown, medium to dense, gravel to 2"max.
	SC	12	33	18	89	36	14	CLAYEY SAND; brown, medium dense, gravel to 1 1/2"max.
	SC	14 15	29 36	13 19	79 84	37 36	34 15 24	GRAVELLY CLAYEY SAND; brown, medium to dense, gravel to 2"max.
	SC	18	32	16	96	50	18 36	CLAYEY SAND; brown, medium to dense, some small gravel.
33.0'	SC	11	30	14	75	26	54	GRAVELLY CLAYEY SAND; brown, very dense, gravel to 2"max., 2-4" cobbles.
36.0'	CL	19	31	14	92	55	36	SANDY CLAY; light brown, hard, gravel to 1 1/2"max.
W.L.45.0'	SC	9 9	26 25	12 10	72 80	22 20	49 80/ * 25	GRAVELLY CLAYEY SAND; light brown, dense, gravel to 2"max.
47.0'	CL	16	30	15	95	72	24	SANDY CLAY; brown, very stiff, some gravel.
51.0'	SC		33	16	78	42	41	GRAVELLY CLAYEY SAND; brown, dense, gravel to 3"max.
54.0'	SM			NP	87	33	33	SILTY SAND; light brown, dense.
58.0'	CL		32	17	95	56	34	SANDY CLAY; brown, hard, some small gravel.
62.0'	SW SM		• 	NP NP	96 85	11 10	80/ 80/ 28	SAND-SILTY SAND; grey very dense, gravel to 2"max.
	SM		•	NP	92	33	21 26	SILTY SAND; grey and brown, medium dense, some small gravel.
	SM		•	NP	84	36	22	GRAVELLY SILTY SAND; grey, medium dense.
70.0'	SM		• •	NP NP	92 94	13 23	50 33	SILTY SAND; grey, dense, gravel to 1 1/2" max., 1-4" cobble.
72.0'	ML		•	NP	98	54	42 18	SANDY SILT; dark grey, very stiff.
76.0'	SW SM			NP	85	12	80/ 80/	SAND-SILTY SAND; grey, very dense, gravel to 2"max.
80.0'	SM			NP NP	80 78	20 17	80/ 80/ 80/	GRAVELLY SILTY SAND, grey very dense, some gravel, sandstone pieces, drilled 45 minutes, no penetration.

bottom

* hit cobble

• VISUAL

T.H. 75-57

EL.476±

Depth		MC	LL	PI	-4	-200	N	
3.5'	CH	29	64	34	100	100		FAT CLAY; grey to brown, medium stiff
7.0'	SC	10	34	19	78	22		GRAVELLY CLAYEY SAND; light brown, dense, gravel to 3"max.
W.L.12.5' 18.0'	SM	9 12 		NP NP NP	79 76 80	20 14 17	27 38 44 30 30 [illegible] [illegible] X	GRAVELLY SILTY SAND; light brown, dense, gravel and cobbles to 5"max.
20.0'	SC		27	12	85	22	[illegible]	CLAYEY SAND; light brown and gray, dense, gravel to 3"max.
23.0'	SM			NP	96	13	45 43	SILTY SAND; grey, dense, some gravel to 1 1/2"max.
27.5'	SP SM			NP NP	100 89	10 6	32 33 12	SAND-SILTY SAND; grey, medium to dense, gravel to 1 1/2", 1-5" cobble.
32.0	SP			NP	85	4	21 8 23	SAND; grey, medium, gravel to 2 1/2" max., 2-4" cobbles.
34.0'	SM				82	13	14	GRAVELLY SILTY SAND; gray, medium.
36.0'	SP SM				81	6	[illegible]* [illegible]**	GRAVELLY SAND-GRAVELLY SILTY SAND, gray, medium dense, gravel to 2"max.
40.0'	SC		39 27	17 12	50 83	23 26	15 [illegible] 20	GRAVELLY CLAYEY SAND, gray, medium, gravel to 3"max., 2-6" cobbles.
42.0'	ML			NP	99	73	47	SANDY SILT; grey, very stiff to hard.
44.0'	SM			NP	78	13	2	GRAVELLY SILTY SAND; grey, very loose, gravel to 2"max., 1-6" cobble.
46.0'	SP SM			NP	63	6	16 33****	GRAVELLY SAND-GRAVELLY SILTY SAND, gray, medium, gravel to 2"max

(drilling discontinued-boulder fell in hole, could not remove.)

* on cobble

** gravel in shoe

****9 blows 45.5-46.0

T.H. 75-56

EL.470±

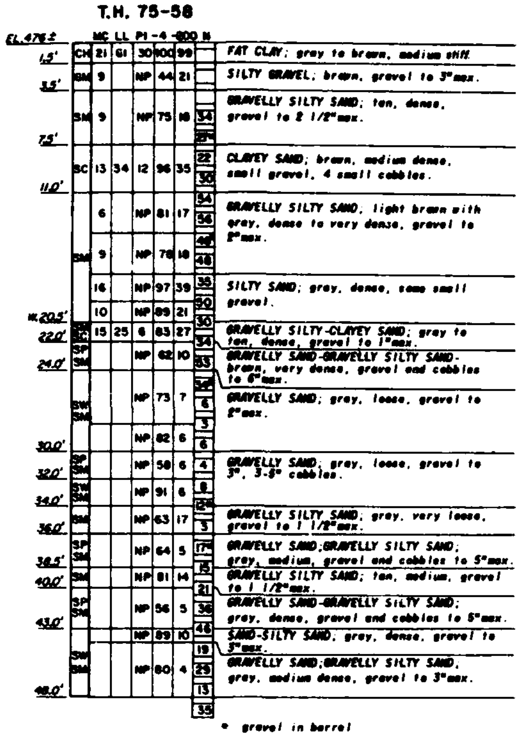
Depth		MC	LL	PI	-4	-200	N	
7.0'	CH	19 3	56 64	23 34	99 99	99 84	8 8 11	FAT CLAY; grey to brown, medium to stiff.
W.L.11.0'	SM	22		NP	99	33	9 7 16	SILTY SAND; gray, loose to medium, gravel to 2"max.
12.5'	ML	24		NP	100	85	22	SANDY SILT; green with black organics, medium, slight small.
14.0'	SM			NP	97	32	5	SILTY SAND; gray, loose, some small cobbles.
15.0'	CL		31	14	100	75	2	SANDY CLAY; dark, gray, very soft, some roots, 1-5" cobble.
27.0'	SM			NP NP NP NP	98 98 97 99	17 21 13 41	15 9 21 13 6 6 5 6	SILTY SAND; gray, loose to medium dense, some small gravel.
29.0'	SW SM			NP	95	12	5	SAND-SILTY SAND; gray, loose, some gravel.
30.0'	CL		44	20	99	85	15	SANDY CLAY; gray, stiff, plastic.
33.0'	SM			NP	97	13	41 17	SILTY SAND; gray, dense to medium, small gravel.
37.0'	SW SM			NP	96	9	19 22	SAND-SILTY SAND; gray, medium dense, small gravel.
38.0'	ML			NP	95	57	11	SANDY SILT; gray, stiff, gravel to 2 1/2"max.
39.0'	SM			NP	92	19	46	SILTY SAND; grey, dense, gravel to 1/2"max.
42.0'	SW SM				93	7	5 9	SAND-SILTY SAND; grey, loose, some small gravel.
44.0'	ML			NP	100	90	22	SANDY SILT; black and green, very stiff,
47.0'	SM			NP NP	95 97	20 16	7 31 39	SILTY SAND; grey, dense to loose, extreme caving, abandoned hole.

T.H.

EL.476±

Depth		MC	LL
1.5'	CH	21	61
3.5'	GM	9	
7.5'	SM	9	
11.0'	SC	13	34
W.L.20.5'	SM	6 9 16 10	
22.0'	SW SC	15	25
24.0'	SP SM		
30.0'	SW SM		
32.0'	SP SM		
34.0'	SW SM		
36.0'	SM		
38.5'	SP SM		
40.0'	SM		
43.0'	SP SM		
48.0'	SW SM		

T.H. 75-58

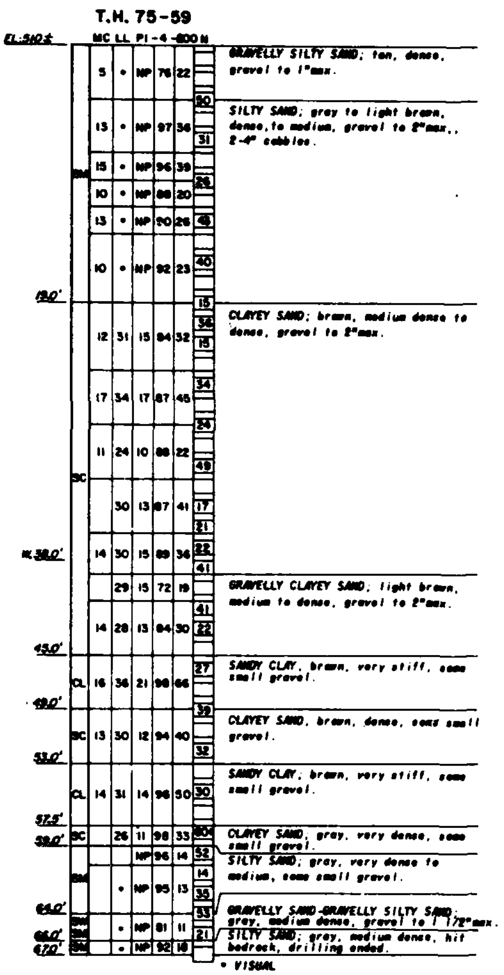


EL.476±

Depth	Symbol	MC	LL	PI	-4	-200	Description
1.5'	CH	21	61	30	100	99	FAT CLAY; grey to brown, medium stiff.
3.5'	GM	9		NP	44	21	SILTY GRAVEL; brown, gravel to 3"max.
7.5'	SM	9		NP	75	16	GRAVELLY SILTY SAND; tan, dense, gravel to 2 1/2"max.
11.0'	SC	13	34	12	96	35	CLAYEY SAND; brown, medium dense, small gravel, 4 small cobbles.
	SM	6		NP	81	17	GRAVELLY SILTY SAND; light brown with grey, dense to very dense, gravel to 2"max.
		9		NP	78	18	
		16		NP	97	39	SILTY SAND; grey, dense, some small gravel.
W.20.5'		10		NP	89	21	
22.0'	SM SC	15	25	6	83	27	GRAVELLY SILTY-CLAYEY SAND; grey to tan, dense, gravel to 1"max.
24.0'	SP SM			NP	62	10	GRAVELLY SAND-GRAVELLY SILTY SAND-brown, very dense, gravel and cobbles to 6"max.
	SW SM			NP	73	7	GRAVELLY SAND; grey, loose, gravel to 2"max.
30.0'				NP	82	6	
32.0'	SP SM			NP	58	6	GRAVELLY SAND; grey, loose, gravel to 3", 3-5" cobbles.
34.0'	SW SM			NP	91	6	
36.0'	SM			NP	63	17	GRAVELLY SILTY SAND; grey, very loose, gravel to 1 1/2"max.
38.5'	SP SM			NP	64	5	GRAVELLY SAND;GRAVELLY SILTY SAND; grey, medium, gravel and cobbles to 5"max.
40.0'	SM			NP	81	14	GRAVELLY SILTY SAND; tan, medium, gravel to 1 1/2"max.
43.0'	SP SM			NP	56	5	GRAVELLY SAND-GRAVELLY SILTY SAND; grey, dense, gravel and cobbles to 5"max.
				NP	89	10	SAND-SILTY SAND; grey, dense, gravel to 3"max.
48.0'	SW SM			NP	80	4	GRAVELLY SAND;GRAVELLY SILTY SAND, grey, medium dense, gravel to 3"max.

* gravel in barrel

T.H. 75-59



EL.510±

Depth	Symbol	MC	LL	PI	-4	-200	Description
	SM	5	•	NP	76	22	GRAVELLY SILTY SAND; tan, dense, gravel to 1"max.
		13	•	NP	97	36	SILTY SAND; grey to light brown, dense, to medium, gravel to 2"max., 2-4" cobbles.
		15	•	NP	96	39	
		10	•	NP	88	20	
		13	•	NP	90	26	
19.0'		10	•	NP	92	23	
	SC	12	31	15	84	32	CLAYEY SAND; brown, medium dense to dense, gravel to 2"max.
		17	34	17	87	45	
		11	24	10	88	22	
			30	13	87	41	
W.38.0'		14	30	15	89	36	
			29	15	72	19	GRAVELLY CLAYEY SAND; light brown, medium to dense, gravel to 2"max.
45.0'		14	28	13	84	30	
49.0'	CL	16	36	21	98	66	SANDY CLAY, brown, very stiff, some small gravel.
53.0'	SC	13	30	12	94	40	CLAYEY SAND, brown, dense, some small gravel.
57.5'	CL	14	31	14	96	50	SANDY CLAY; brown, very stiff, some small gravel.
59.0'	SC		26	11	98	33	CLAYEY SAND, grey, very dense, some small gravel.
	SM			NP	96	14	SILTY SAND; gray, very dense to medium, some small gravel.
64.0'			•	NP	95	13	
66.0'	SW SM		•	NP	81	11	GRAVELLY SAND-GRAVELLY SILTY SAND; grey, medium dense, gravel to 1 1/2"max.
67.0'	SM		•	NP	92	18	SILTY SAND; grey, medium dense, hit bedrock, drilling ended.

• VISUAL

NOTES:-

1. For location of test holes see plate 18.
2. For legend see plate 25.
3. TH 75-57 through 60 were drilled during October 1975 with a 16-inch diameter bucket-type power auger.
4. All holes drilled to desired depth, except when indicated.

VERTICAL SCALE
5 0 5 10 15

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.H. 75-56 THRU T.H. 75-60

SUBMITTED BY:

DATE APPROVED:

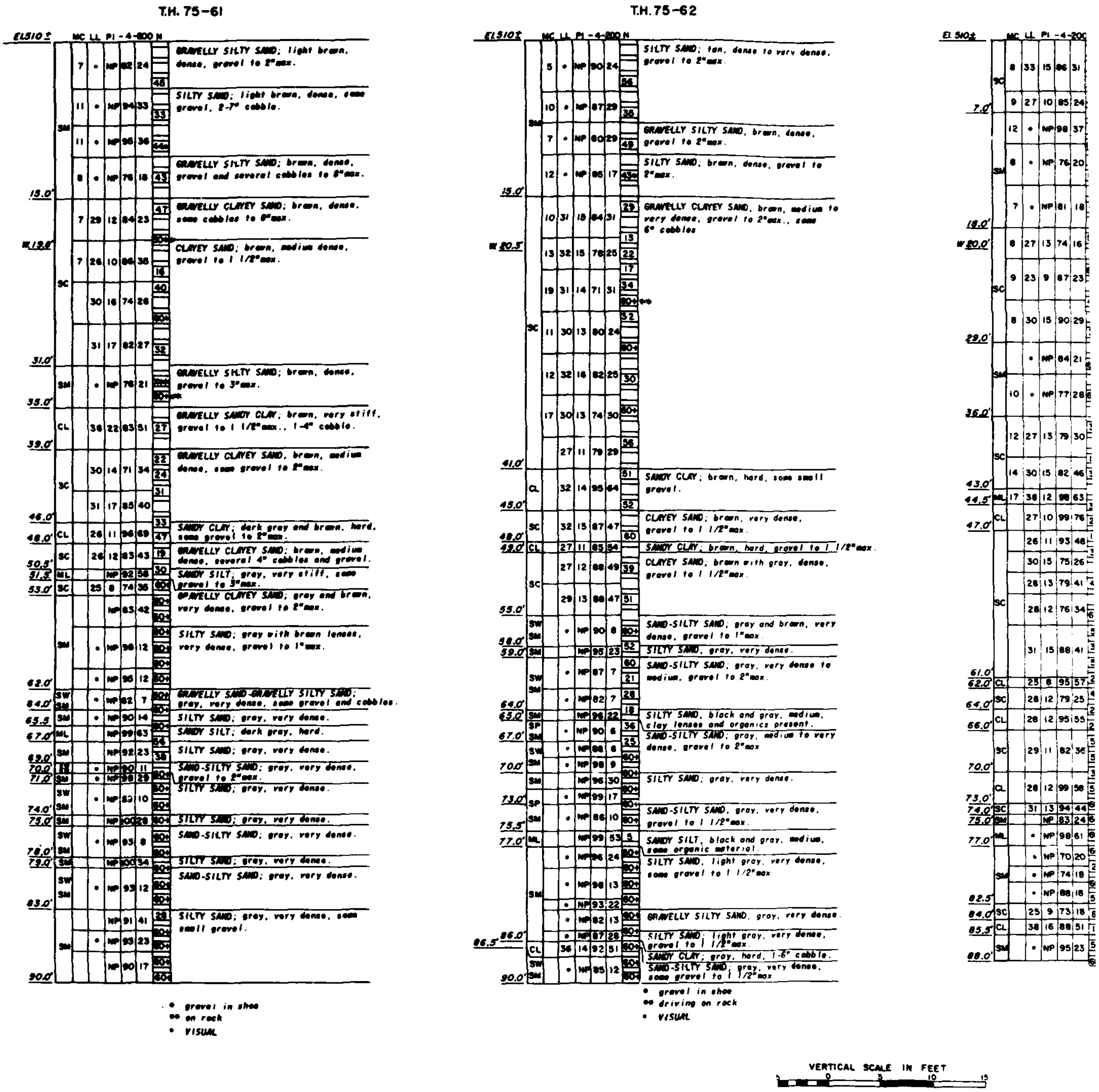
SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

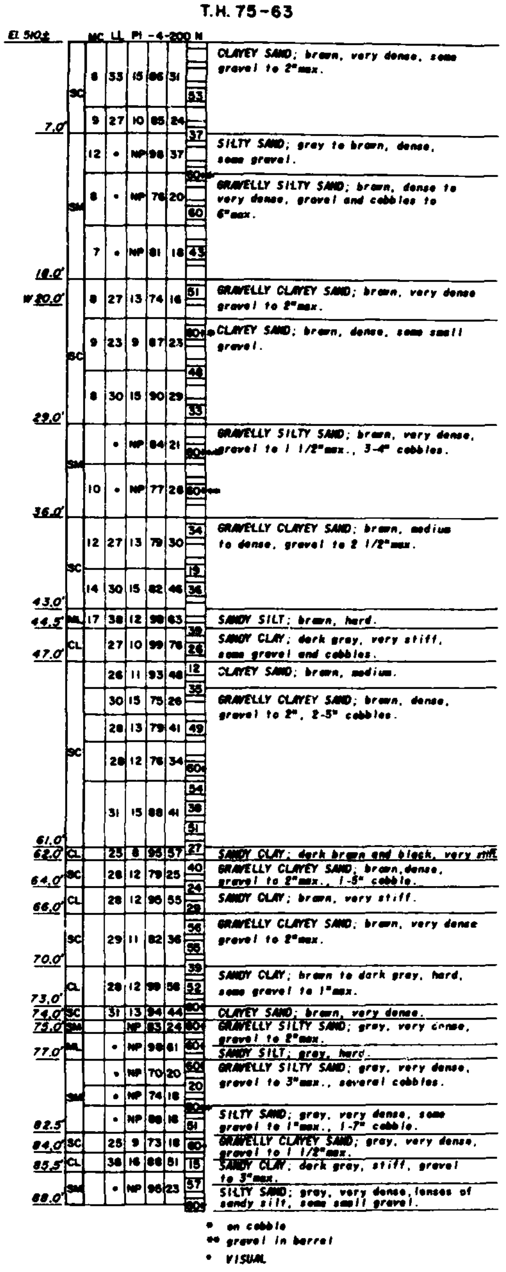
2

U.S. ARMY ENGINEER DISTRICT



CORPS OF ENGINEERS

T.H. 75-63

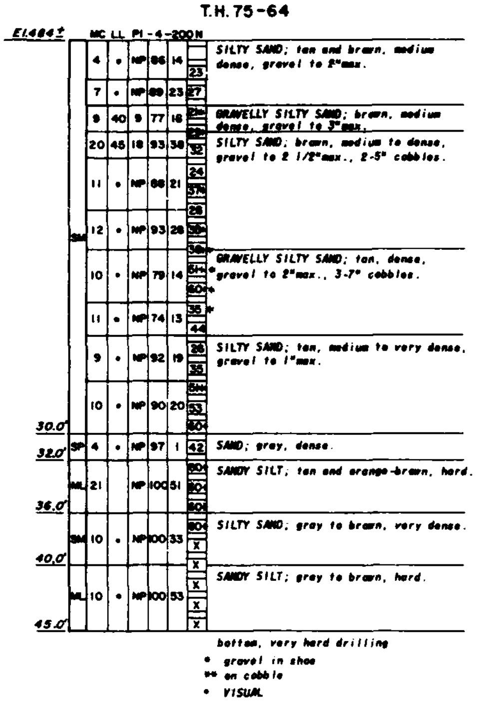


EL 510±

Elev.	Soil	MC	LL	PI	-4	-200	N	Description
	SC	8	33	15	86	31	53	CLAYEY SAND; brown, very dense, some gravel to 2"max.
7.0'		9	27	10	85	24	37	
	SM	12	•	NP	98	37	60+*	SILTY SAND; grey to brown, dense, some gravel.
		8	•	NP	76	20	60	GRAVELLY SILTY SAND; brown, dense to very dense, gravel and cobbles to 6"max.
18.0'		7	•	NP	81	18	43	
W 20.0'	SC	8	27	13	74	16	51	GRAVELLY CLAYEY SAND; brown, very dense gravel to 2"max.
		9	23	9	87	23	60+* 48	CLAYEY SAND; brown, dense, some small gravel.
29.0'		8	30	15	90	29	33	
	SM		•	NP	84	21	60+**	GRAVELLY SILTY SAND; brown, very dense, gravel to 1 1/2"max., 3-4" cobbles.
36.0'		10	•	NP	77	28	60+**	
	SC	12	27	13	79	30	34 19	GRAVELLY CLAYEY SAND; brown, medium to dense, gravel to 2 1/2"max.
43.0'		14	30	15	82	46	36	
44.5'	ML	17	38	12	98	63		SANDY SILT; brown, hard.
47.0'	CL		27	10	99	78	39 26	SANDY CLAY; dark grey, very stiff, some gravel and cobbles.
	SC		26	11	93	48	12 35	CLAYEY SAND; brown, medium.
			30	15	75	26		GRAVELLY CLAYEY SAND; brown, dense, gravel to 2", 2-5" cobbles.
			28	13	79	41	49	
			28	12	76	34	60+	
61.0'			31	15	88	41	54 38 51	
62.0'	CL		25	8	95	57	27	SANDY CLAY; dark brown and black, very stiff
64.0'	SC		28	12	79	25	40 24	GRAVELLY CLAYEY SAND; brown, dense, gravel to 2"max., 1-5" cobble.
66.0'	CL		28	12	96	55	29	SANDY CLAY; brown, very stiff.
70.0'	SC		29	11	82	36	56 55	GRAVELLY CLAYEY SAND; brown, very dense gravel to 2"max.
73.0'	CL		28	12	99	58	39 52	SANDY CLAY; brown to dark grey, hard, some gravel to 1"max.
74.0'	SC		31	13	94	44	60+	CLAYEY SAND; brown, very dense.
75.0'	SM			NP	83	24	60+	GRAVELLY SILTY SAND; grey, very dense, gravel to 2"max.
77.0'	ML		•	NP	98	61	60+	SANDY SILT; grey, hard.
	SM		•	NP	70	20	60+ 20	GRAVELLY SILTY SAND; grey, very dense, gravel to 3"max., several cobbles.
			•	NP	74	18	60+*	
82.5'			•	NP	88	18	51	SILTY SAND; grey, very dense, some gravel to 1"max., 1-7" cobble.
84.0'	SC		25	9	73	18	60+	GRAVELLY CLAYEY SAND; grey, very dense, gravel to 1 1/2"max.
85.5'	CL		38	16	88	51	15	SANDY CLAY; dark grey, stiff, gravel to 3"max.
88.0'	SM		•	NP	96	23	57 60+	SILTY SAND; grey, very dense, lenses of sandy silt, some small gravel.

* on cobble
** gravel in barrel
• VISUAL

T.H. 75-64



El.484±

Elev.	Soil	MC	LL	PI	-4	-200	N	Description
	SM	4	•	NP	86	14	23	SILTY SAND; tan and brown, medium dense, gravel to 2"max.
		7	•	NP	89	23	27	
		9	40	9	77	18	21+ 29+	GRAVELLY SILTY SAND; brown, medium dense, gravel to 3"max.
		20	45	18	93	38	32	SILTY SAND; brown, medium to dense, gravel to 2 1/2"max., 2-5" cobbles.
		11	•	NP	88	21	24 37+ 28	
		12	•	NP	93	28	50+ 50+*	
		10	•	NP	79	14	51+* 60+*	GRAVELLY SILTY SAND; tan, dense, gravel to 2"max., 3-7" cobbles.
		11	•	NP	74	13	35* 44	
		9	•	NP	92	19	26 35	SILTY SAND; tan, medium to very dense, gravel to 1"max.
30.0'		10	•	NP	90	20	51+ 53 60+	
32.0'	SP	4	•	NP	97	1	42	SAND; grey, dense.
36.0'	ML	21		NP	100	51	60+ 60+ 60+	SANDY SILT; tan and orange-brown, hard.
40.0'	SM	10	•	NP	100	33	60+ X X	SILTY SAND; grey to brown, very dense.
45.0'	ML	10	•	NP	100	53	X X X	SANDY SILT; grey to brown, hard.

bottom, very hard drilling
* gravel in shoe
** on cobble
• VISUAL

NOTES:

1. For location of test holes see plate 18
2. For legend see plate 25.
3. TH 75-61 through 64 were drilled during November 1975 with a 16-inch diameter bucket-type power auger.
4. All holes drilled to desired depth, except when indicated.

VERTICAL SCALE IN FEET
0 5 10 15

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS

T.H. 75-61 THRU T.H. 75-64

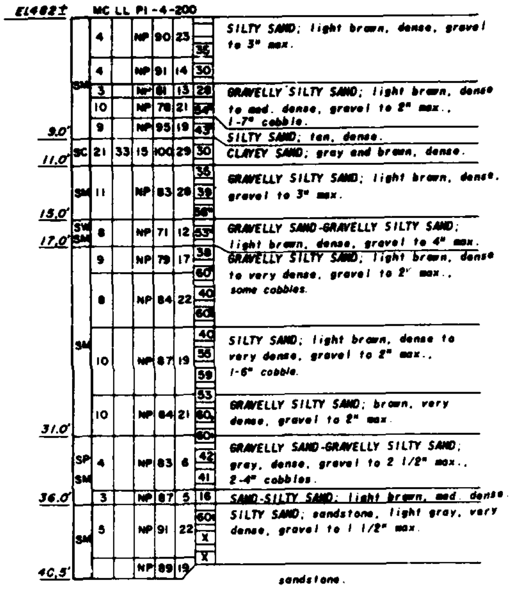
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

1

2

U.S. ARMY ENGINEER DISTRICT

T.H. 75-65



SILTY SAND; light brown, dense, gravel to 3" max.

GRAVELLY SILTY SAND; light brown, dense to med. dense, gravel to 2" max., 1-7" cobble.

SILTY SAND; tan, dense.

CLAYEY SAND; gray and brown, dense.

GRAVELLY SILTY SAND; light brown, dense, gravel to 3" max.

GRAVELLY SAND-GRAVELLY SILTY SAND; light brown, dense, gravel to 4" max.

GRAVELLY SILTY SAND; light brown, dense to very dense, gravel to 2" max., some cobbles.

SILTY SAND; light brown, dense to very dense, gravel to 2" max., 1-6" cobble.

GRAVELLY SILTY SAND; brown, very dense, gravel to 2" max.

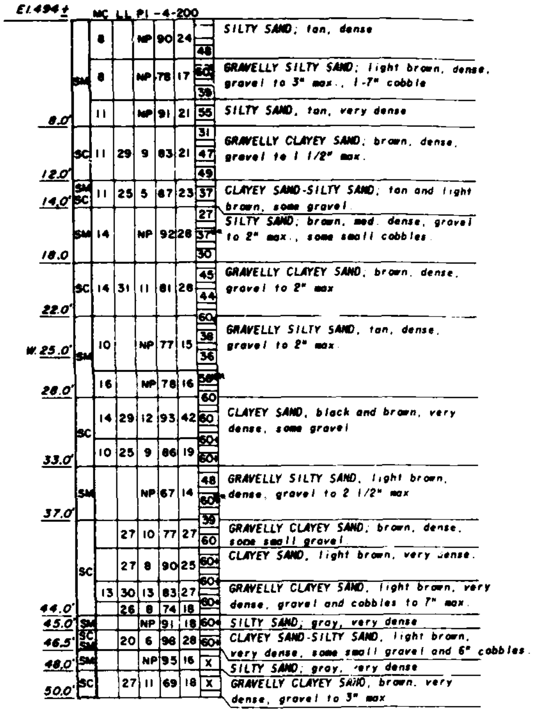
GRAVELLY SAND-GRAVELLY SILTY SAND; gray, dense, gravel to 2 1/2" max., 2-4" cobbles.

SAND-SILTY SAND; light brown, med. dense.

SILTY SAND; sandstone, light gray, very dense, gravel to 1 1/2" max.

sandstone.

T.H. 75-66



SILTY SAND; tan, dense

GRAVELLY SILTY SAND; light brown, dense, gravel to 3" max., 1-7" cobble

SILTY SAND, tan, very dense

GRAVELLY CLAYEY SAND; brown, dense, gravel to 1 1/2" max.

CLAYEY SAND-SILTY SAND; tan and light brown, some gravel

SILTY SAND; brown, med. dense, gravel to 2" max., some small cobbles

GRAVELLY CLAYEY SAND; brown, dense, gravel to 2" max

GRAVELLY SILTY SAND, tan, dense, gravel to 2" max

CLAYEY SAND, black and brown, very dense, some gravel

GRAVELLY SILTY SAND, light brown, dense, gravel to 2 1/2" max

GRAVELLY CLAYEY SAND; brown, dense, some small gravel

CLAYEY SAND, light brown, very dense.

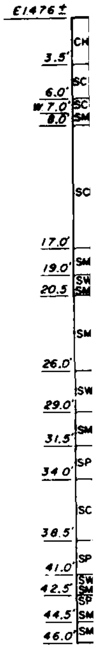
GRAVELLY CLAYEY SAND, light brown, very dense, gravel and cobbles to 7" max.

SILTY SAND; gray, very dense

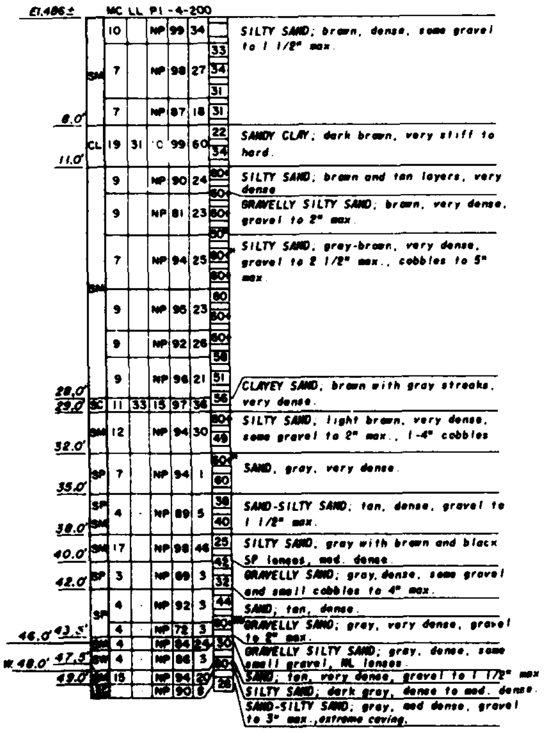
CLAYEY SAND-SILTY SAND, light brown, very dense, some small gravel and 6" cobbles.

SILTY SAND; gray, very dense

GRAVELLY CLAYEY SAND, brown, very dense, gravel to 3" max



T.H. 75-69



SILTY SAND; brown, dense, some gravel to 1 1/2" max.

SANDY CLAY; dark brown, very stiff to hard.

SILTY SAND; brown and tan layers, very dense

GRAVELLY SILTY SAND; brown, very dense, gravel to 2" max.

SILTY SAND; grey-brown, very dense, gravel to 2 1/2" max., cobbles to 5" max.

CLAYEY SAND; brown with gray streaks, very dense.

SILTY SAND; light brown, very dense, some gravel to 2" max., 1-4" cobbles

SAND, gray, very dense.

SAND-SILTY SAND; tan, dense, gravel to 1 1/2" max.

SILTY SAND; gray with brown and black SP lenses, med. dense.

GRAVELLY SAND; gray, dense, some gravel and small cobbles to 4" max.

SAND; tan, dense.

GRAVELLY SAND; gray, very dense, gravel to 2" max.

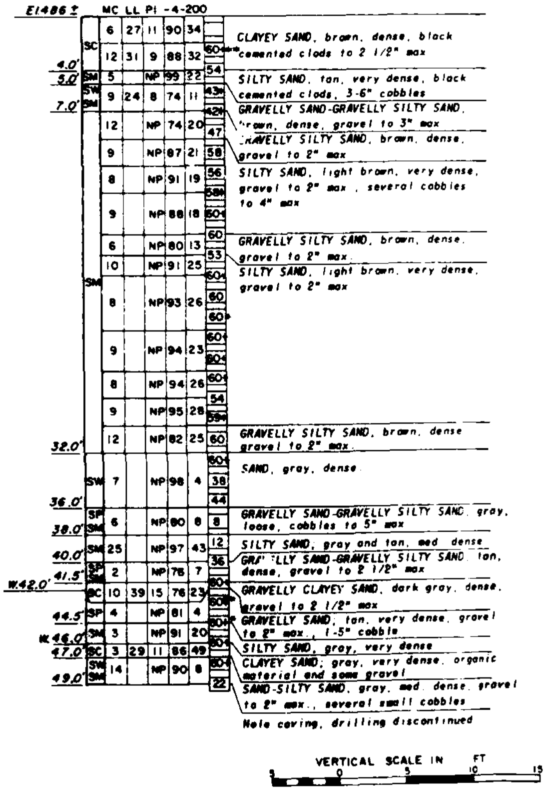
GRAVELLY SILTY SAND; gray, dense, some small gravel, ML lenses.

SAND; tan, very dense, gravel to 1 1/2" max

SILTY SAND; dark gray, dense to med. dense.

SAND-SILTY SAND; gray, med dense, gravel to 3" max., extreme caving.

T.H. 75-70



CLAYEY SAND, brown, dense, black cemented clods to 2 1/2" max

SILTY SAND, tan, very dense, black cemented clods, 3-6" cobbles

GRAVELLY SAND-GRAVELLY SILTY SAND, brown, dense, gravel to 3" max

GRAVELLY SILTY SAND, brown, dense, gravel to 2" max

SILTY SAND, light brown, very dense, gravel to 2" max, several cobbles to 4" max

GRAVELLY SILTY SAND, brown, dense, gravel to 2" max.

SILTY SAND, light brown, very dense, gravel to 2" max

GRAVELLY SILTY SAND, brown, dense gravel to 2" max.

SAND, gray, dense

GRAVELLY SAND-GRAVELLY SILTY SAND, gray, loose, cobbles to 5" max

SILTY SAND, gray and tan, med dense

GRAVELLY SAND-GRAVELLY SILTY SAND, tan, dense, gravel to 2 1/2" max

GRAVELLY CLAYEY SAND, dark gray, dense, gravel to 2 1/2" max

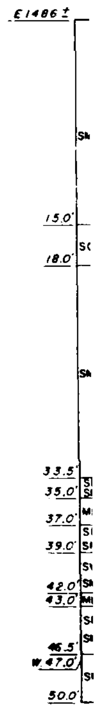
GRAVELLY SAND, tan, very dense, gravel to 2" max., 1-5" cobble

SILTY SAND, gray, very dense

CLAYEY SAND; gray, very dense, organic material and some gravel

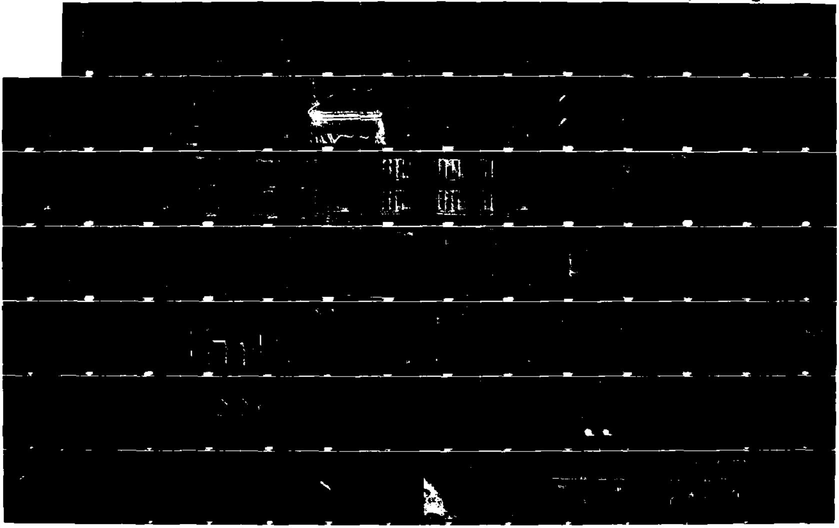
SAND-SILTY SAND, gray, med. dense, gravel to 2" max., several small cobbles

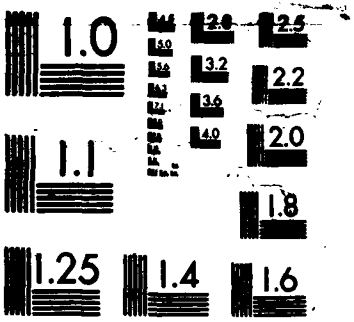
Hole caving, drilling discontinued



AD-A204 542 SANTA ANA RIVER DESIGN MEMORANDUM NUMBER 1 PHASE 2 GDM 5/10
ON THE SANTA ANA R..(U) ARMY ENGINEER DISTRICT LOS
ANGELES CA AUG 88

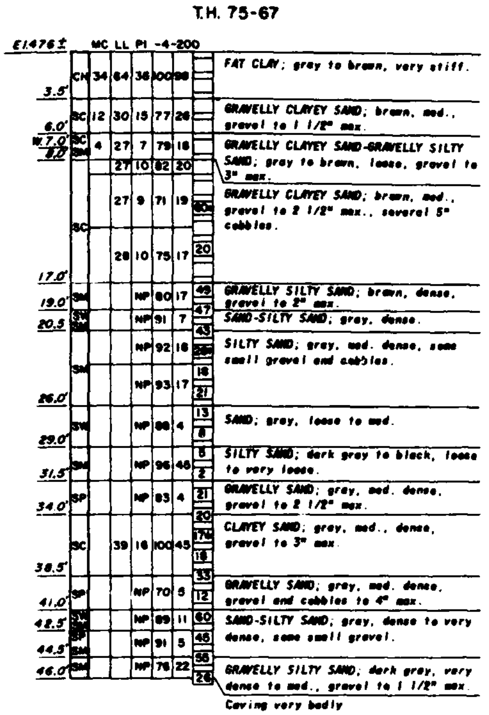
UNCLASSIFIED F/G 13/2 NL



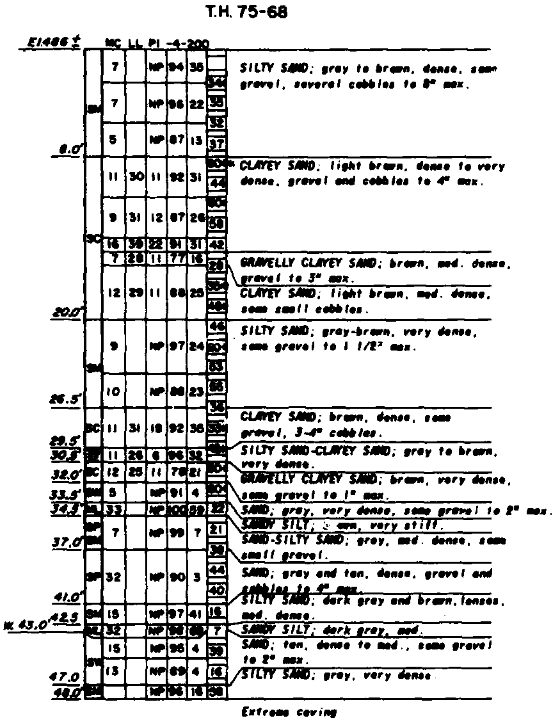


MICROC

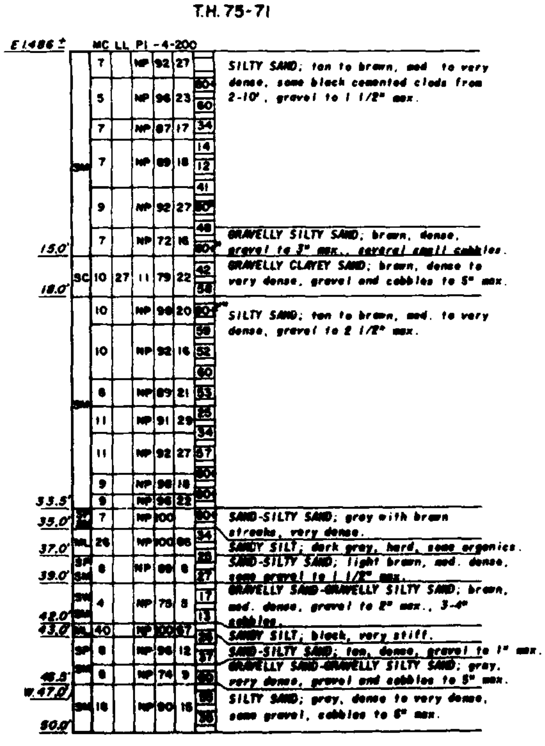
T.H. 75-67



T.H. 75-68



T.H. 75-71



Notes:

1. *TH 75-65 through 75-71 were drilled during November and December 1975 with a 16-inch diameter bucket-type power auger.*
2. *For locations of test holes see Plate 18*
3. *For legend see Plate 25.*
4. *All holes drilled to desired depths except when indicated.*

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

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U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
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SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS

T.H. 75-65 THRU T.H. 75-71

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET

1

2

PLATE B-36

T.H. 79-1

EL. 545.0'±	LOG	MC	LL	PI	-4	-200	N	
1.5'	ML	11	26	NP	100	61		SANDY SILT: Light brown, cohesive
		11		NP	100	34	[illegible]	SILTY SAND: Light brown, cohesive, dense
	SM	4		NP	97	42	[illegible]	very dense
10.5'		12	21	NP	100	36	24	very little cohesion, dense
13.5'	ML	24	55	NP	99	96	47	SILT: Brown to red, cohesive, dense
16.5'	SM-SC	7	18	5	94	31	19	GRAVELLY SILTY SAND-GRAVELLY CLAYEY SAND: Light brown, medium dense
19.5'	SM	3		NP	99	19		SILTY SAND: Tan to light brown

T.H. 79-2

EL. 543.0'±	LOG	MC	LL	PI	-4	-200	N	
1.5'	CL	11	26	13	98	64		SANDY CLAY: Dark brown, moist, cohesive
4.5'	ML-CL	14	24	6	100	84	18	SANDY SILT-SANDY CLAY: Brown, cohesive, very stiff
		15	30	17	100	89	25	SANDY CLAY: Brown, cohesive, very stiff
	CL	21	37	13	100	83	17	red-brown
13.5'		16	29	13	89	62	[illegible]	
16.5'	SP-SM	8		NP	76	6	50	GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, very dense
19.5'	SP-SM	8		NP	77	9		

T.H. 79-4

EL. 550.0'±	LOG	MC	LL	PI	-4	-200	N	
		13	33	16	100	82		SANDY CLAY: Red-brown, cohesive, very stiff
4.5'	CL	19	34	16	100	83	30	
7.5'	SM	9		NP	99	24	16	SILTY SAND: Brown, cohesive, medium dense
	SP-SM	4		NP	92	6	25	SAND-SILTY SAND: Brown, medium dense
13.5'		4		NP	97	9	[illegible]	Tan to brown
	CL	13	27	10	100	69	17	SANDY CLAY: Red-brown, cohesive, very stiff
16.5'		13	26	13	99	64		
19.5'	SM	13	21	3	97	42		SILTY SAND: Red brown, cohesive; 15% cobbles to 8"

T.H. 79-5

EL. 529.0'±	LOG	MC	LL	PI	-4	-200	N	
1.5'	ML-CL	8	24	8	94	66		SANDY SILT-SANDY CLAY: Brown, cohesive
4.5'	GC	8		NP	47	15		CLAYEY SANDY GRAVEL: Brown, cohesive, 5% cobbles to 6"
7.5'	SM	9		NP	75	16		SILTY GRAVELLY SAND: Reddish brown, gravel to 1 1/2"
	SP-SM	8		NP	89	12		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, 15% cobbles to 6"
13.5'		4		NP	90	8		
16.5'	SM	11		NP	84	30		GRAVELLY SILTY SAND: Red-brown, cohesive, gravel to 1 1/2"
19.5'	SP-SM	4		NP	64	6		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, gravel to 1 1/2"

T.H. 79-7

EL. 536.0'±	LOG	MC	LL	PI	-4	-200	N	
1.5'	ML-CL	13	23	5	99	80		SANDY SILT-SANDY CLAY: Brown, cohesive
		17	43	25	96	86	[illegible]	FAT CLAY: Brown, cohesive, hard
7.5'	CL	19	24	10	96	89		SANDY CLAY: Brown, cohesive, gravel to 1 1/2", 10% cobbles to 4"
10.5'	SC	12	23	10	96	39		CLAYEY SAND: Red-brown, cohesive
		7	19	NP	72	12		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, gravel to 1 1/2", 10% cobbles to 4"
	SP-SM	3		NP	90	10		SAND-SILTY SAND: Brown, gravel to 1", 10% cobbles to 4"
19.5'		3		NP	89	7		GRAVELLY SAND-SILTY GRAVELLY SAND: Light brown, gravel to 1", 10% cobbles to 4"

T.H. 79-8

EL. 532.0'±	LOG	MC	LL	PI	-4	-200	N	
1.5'	SC	10	31	16	97	43		CLAYEY SAND: Brown, cohesive
4.5'	SM	9		NP	89	20		SILTY SAND: Brown, cohesive, gravel to 1 1/2", 8% cobbles to 5"
		6		NP	86	12	21	SAND-SILTY SAND: Brown, medium dense gravel to 1", 4% cobbles to 6"
	SP-SM	7		NP	80	5	31	GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, dense, gravel to 2", 8% cobbles to 5"
		4		NP	89	5		
17.0'		5		NP	76	7		
19.5'	SM-SC	9	20	8	89	8		SAND-CLAYEY SAND: Red-brown, gravel to 1", 10% cobbles to 4"

T.H. 79-10

EL. 544.0'±	LOG	MC	LL	PI	-4	-200	N	
		4	32	13	100	75		SANDY CLAY: Brown, cohesive, organics
4.5'	CL	20	32	10	100	82		
	SP-SM	8		NP	67	11	[illegible]	GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, medium dense, 6% cobbles to 4"
10.5'		5		NP	82	12		gravel to 1 1/2"
13.5'	SP-SM	3		NP	89	6		1-6" cobble
16.5'	SM	12		NP	89	20		SILTY SAND: Brown, cohesive, gravel to 3/4", 6% cobbles to 5"
19.5'	SP-SM	4		NP	83	6		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, gravel to 1", 6% cobbles to 6"

T.H. 79-11

EL. 547.0'±	LOG	MC	LL	PI	-4	-200	N	
1.5'	CL	11	29	10	100	61		SANDY CLAY: Red-brown, cohesive
4.5'	ML	27	34	5	100	96	31	SILT: Brown, cohesive, dense
7.5'	SM	16		NP	99	39	[illegible]	SILTY SAND: Brown, cohesive, dense
10.5'	SP-SM	3		NP	76	12		GRAVELLY SAND-SILTY GRAVELLY SAND: Tan to light brown, gravel to 2"
12.0'	ML-CL	16	25	5	98	70	[illegible]	SANDY SILT-SANDY CLAY: Red-brown, cohesive, very stiff
13.5'	SM	6		NP	86	13		SILTY SAND: Brown, gravel to 3/4"
16.5'	SP-SM	4		NP	92	11		SAND-SILTY SAND: Brown, gravel to 3/4"
19.5'	SM	9		NP	99	39		SILTY SAND: Brown

EL. 548.0'± LOG

CL

10.5'

13.5'

19.5'

EL. 524.0'± LOG

1.5' CL

4.5' SM

10.5'

13.5'

16.5'

19.5'

EL. 532.0'± LOG

1.5' CL

4.5'

7.5'

10.5'

13.5'

16.5' SW

19.5'

EL. 542.0'± LOG

1.5' CL

4.5'

7.5'

10.5'

13.5'

16.5'

19.5'

T.H. 79-3

EL. 548.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	Description
	CL	11	32	17	100	72		SANDY CLAY: Brown, cohesive, very stiff
		16	28	10	100	67	17	
		21	33	14	100	71	27	light brown
10.5'		20	30	12	100	[illegible]	[illegible]	
	SM	12	20	2	[illegible]	41	41	SILTY SAND: Brown, cohesive, dense
13.5'		13	19	NP	[illegible]	[illegible]		
	[illegible]	3		NP	80	11		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, 10% cobbles to 5"
19.5'	[illegible]	2		NP	77	7		tan to brown

T.H. 79-6

EL. 524.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	Description
1.5'	CL	11	24	8	97	75		SANDY CLAY: Dark brown, cohesive
4.5'	SM	9		NP	94	21	38	GRAVELLY SILTY SAND: Dense, gravel to 1 1/2"
	[illegible]	7		NP	83	10		GRAVELLY SAND-SILTY GRAVELLY SAND: Dark brown, 10% cobbles to 4"
10.5'		6		NP	88	7		SAND-SILTY SAND: Brown, gravel to 1 1/2"
13.5'	[illegible]	7		NP	71	8		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, 10% cobbles to 4"
16.5'	[illegible]	6		NP	88	6		gravel to 1 1/2"
19.5'	[illegible]	8		NP	93	11		SAND-SILTY SAND: Brown

T.H. 79-9

EL. 532.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	Description
1.5'	CL	10	33	17	98	67		SANDY CLAY: Brown, cohesive
4.5'	[illegible]	5		NP	55	11		SANDY GRAVEL-SILTY SANDY GRAVEL: Brown, cohesive, gravel to 1 1/2", 10% cobbles to 4"
7.5'	[illegible]	5		NP	84	8		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, gravel to 1 1/2", 10% cobbles to 4"
10.5'	[illegible]	5		NP	94	8		SAND-SILTY SAND: Tan to brown, gravel to 3/4"
13.5'	[illegible]	6		NP	79	13		SILTY GRAVELLY SAND: Light brown, gravel to 1 1/2", 10% cobbles to 4"
16.5'	[illegible]	4		NP	88	4		SAND: Light brown, gravel to 1 1/2", 10% cobbles to 4"
19.5'	SM	4		NP	80	5		GRAVELLY SAND-SILTY GRAVELLY SAND: Light brown, gravel to 1 1/2", 10% cobbles to 4"

T.H. 79-12

EL. 542.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	Description
1.5'	CL	14	34	21	100	84		SANDY CLAY: Dark brown, cohesive
4.5'	SM	12	19	2	92	38	[illegible]	SILTY SAND: Brown, cohesive, dense
7.5'	[illegible]	4		NP	58	8		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, gravel to 1 1/2"
10.5'	[illegible]	12		NP	49	8		SANDY GRAVEL-SILTY SANDY GRAVEL: Brown, gravel to 6"
13.5'	ML	9	22	NP	98	67		SANDY SILT: Brown, cohesive
16.5'	SM	9		NP	88	[illegible]		SILTY SAND: Light brown, gravel to 1"
19.5'	[illegible]	8		NP	94	8		GRAVELLY SAND-SILTY GRAVELLY SAND: Light brown, gravel to 1/2"

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS More than half of material is larger than No. 200 sieve size.	GRAVELS More than half of coarse fraction is larger than No. 4 sieve size.	Clean gravels	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.
		Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS More than half of coarse fraction is smaller than No. 4 sieve size.	Clean sands	SW	Well-graded sands, gravelly sands, little or no fines.
			SP	Poorly-graded sands, gravelly sands, little or no fines.
		Sands with fines	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS More than half of material is smaller than No. 200 sieve size.	SILTS AND CLAYS	Low liquid limit	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts, with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
		High liquid limit	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
Highly organic soils			Pt	Peat and other highly organic soils.

NOTES:

1. Boundary Classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example, GW-GC, well-graded gravel-sand mixture with clay binder.
2. All sieve sizes on this chart are U. S. Standard.
3. The terms "silt" and "clay" are used respectively to distinguish materials exhibiting lower plasticity from those with higher plasticity. The minus no. 200 sieve material is silt if the liquid limit and plasticity index plot below the "A" line on the plasticity chart (Table VI, Military Standard 619B), and is clay if the liquid limit and plasticity index plot above the "A" line on the chart.
4. For a complete description of the Unified Soil Classification System, see "Military Standard 619B" dated 20 March 1976

LEGEND

T.H. ●	LOCATION AND NUMBER OF TEST HOLE.
MC	FIELD MOISTURE CONTENT IN PERCENT OF DRY WEIGHT.
LL	LIQUID LIMIT.
PI	PLASTICITY INDEX (LIQUID LIMIT MINUS PLASTIC LIMIT).
NP	NONPLASTIC
-4	PERCENT OF MATERIAL BY WEIGHT PASSING NO. 4 SIEVE.
-200	PERCENT OF MATERIAL BY WEIGHT PASSING NO. 200 SIEVE.
N	NUMBER OF BLOWS OF A 140-POUND DRIVEHAMMER FALLING 30 INCHES REQUIRED TO DRIVE A SAMPLING SPOON ONE FOOT. OUTSIDE DIAMETER OF SPOON IS 2 INCHES; INSIDE DIAMETER IS 1-3/8 INCHES. PROCEDURE IS CALLED STANDARD PENETRATION TEST.
▽	DEPTH TO WATER

NOTE:

1. See plate 17 for location of borings.
2. TH 79-1 to 12 were drilled in November 1979 with a 16-inch bucket auger.

VERTICAL SCALE: 1 INCH = 5 FEET

SCALE 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
TH79-1 THRU TH79-12

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___-B-___
DISTRICT FILE NO.
SHEET

PLATE [illegible]

i

VALUE ENGINEER

TH 79-13

EL. 480.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
		3		NP	91	14		SILTY SAND: Tan to light brown, gravel to 1 1/2", 10% cobbles to 6"
	SM	13		NP	97	[illegible]		brown
7.5'		7		NP	96	28	31	dense, gravel to 3/4", 5% cobbles to 6"
10.5'	SM-SC	20	23	6	96	30		SILTY SAND-CLAYEY SAND: Red-brown, cohesive
		19		NP	96	31	13	SILTY SAND: Red-brown, medium dense, cohesive, gravel to 3/4"
16.5'	SM	14		NP	90	30	27	dark brown, gravel to 1", 5% cobbles to 6"
19.5'	CL	12	27	8	97	87		SANDY CLAY: Dark brown to black

TH 79-14

EL. 500.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
		3		NP	97	20		SILTY SAND: Tan to light brown, cohesive
4.5'	SM	6		NP	88	15		brown, little cohesion, gravel to 1"
		4		NP	78	9	41	GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, gravel to 3/4", dense
10.5'	SP-SM	7		NP	50	11	21	SAND-SILTY SAND: Brown, gravel to 3/4", medium dense
13.5'	SM	6		NP	89	13	14	SILTY SAND: Brown to tan, gravel to 3/4", medium dense
	SP-SM	7		NP	87	9	14	SAND-SILTY SAND: Tan to brown, gravel to 1", medium dense
19.5'				NP	92	8		

TH 79-17

EL. 476.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
1.5'	CH	42	57	28	100	100		FAT CLAY: Dark brown, cohesive
		13		NP	76	18		SILTY GRAVELLY SAND: Light brown, cohesive, gravel to 1 1/2"
9.0' W		18		NP	79	29		GRAVELLY SILTY SAND: Light brown, cohesive, gravel to 3"
	SM	14		NP	79	18		SILTY GRAVELLY SAND: Light brown, cohesive, gravel to 1 1/2"
		25		NP	73	17		
13.5'		29		NP	83	20		GRAVELLY SILTY SAND: Light brown, cohesive, gravel to 1 1/2"
16.5'	SP-SM	31		NP	57	12		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown cohesive, 10% cobbles to 6"
19.5'	SM	27		NP	89	27		SILTY SAND: Brown, cohesive, gravel to 1 1/2"
		20		NP	93	7		SAND-SILTY SAND: Brown
		19		NP	83	10		GRAVELLY SAND-SILTY GRAVELLY SAND: Light brown, gravel to 1 1/2"
		20		NP	88	5		SAND-SILTY SAND: Light brown, gravel to 1 1/2"
	SP-SM	21		NP	95	10		gravel to 3/4"
		14		NP	96	9		
		21		NP	100	12		dark gray
40.5'		15		NP	84	11		GRAVELLY SAND-SILTY GRAVELLY SAND: Dark gray, gravel to 1 1/2"
43.5'	SP	20		NP	84	4		GRAVELLY SAND: Dark gray gravel to 1 1/2"
		19		NP	90	6		SAND-SILTY SAND: Dark gray, gravel to 1 1/2"
50.0'	SP-SM	13		NP	74	8		GRAVELLY SAND-SILTY GRAVELLY SAND: Dark gray, gravel to 1 1/2"

TH 79-21

EL. 480.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
1.5'	CH	41	59	30	100	98		FAT CLAY: Dark brown, cohesive
		13		NP	94	32		SILTY SAND: Brown, cohesive, gravel to 3/4"
		21		NP	96	28	11	medium dense
8.0' W		21		NP	80	30		GRAVELLY SILTY SAND: Brown, cohesive gravel to 3"
	SM	26		NP	91	30	15	SILTY SAND: Brown, cohesive, gravel to 1 1/2", medium dense
		24		NP	100	34	15	grayish black
				NP	100	40		
18.0'				NP	95	14	5	gravel to 1 1/2", loose
				NP	96	12	17	SAND-SILTY SAND: Dark gray, gravel to 1 1/2", medium dense
				NP	100	9	9	loose
				NP	95	12	[illegible]	medium dense
	SP-SM			NP	78	9	11	GRAVELLY SAND-SILTY GRAVELLY SAND: Dark gray, gravel to 3", medium dense..
				NP	79	9		
				NP	81	8		
				NP	93	10		SAND-SILTY SAND: Dark gray, gravel to 1 1/2"
[illegible]				NP	94	11		
44.0'	SM			NP	[illegible]	[illegible]		SILTY SAND: Dark gray, cohesive
[illegible]	SP-SM			NP	[illegible]	9		SAND-SILTY SAND: Dark gray
[illegible]	SM			NP	[illegible]	[illegible]		SILTY SAND: Dark gray

TH 79-18

EL. 498.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
		4		NP	94	16		SILTY SAND: Tan to light brown, gravel to 3/4"
		8		NP	95	28		brown, cohesive, gravel to 1 1/2"
	SM	11		NP	99	31	17	light brown, medium dense
10.5'		8		NP	96	15	13	tan to light brown, gravel to 3/4", medium dense
13.5'	SP-SM	6		NP	85	11	21	GRAVELLY SAND-SILTY GRAVELLY SAND: Light brown, gravel to 3", medium dense
		10		NP	100	21	35	SILTY SAND: Light brown, dense
19.5'	SM	7		NP	98	14		gravel to 3/4"

TH 79-22

EL. 479.0'±

Depth	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
1.5'	CH	47	57	29	100	98	5	FAT CLAY: Dark brown & red brown, cohesive, medium stiff
		21	25	3	94	46	2	SILTY SAND: Dark brown, cohesive, gravel to 1 1/2", very loose
4.5' W		21	24	4	93	43	2	
	SM	25	26	4	95	42	1	
10.5'		26			93	44		

Stop drilling due to cave in

TH

EL. 486.0'±

Depth	LOG	MC
		3
		7
	SM	8
10.5'		10
12.0'	SP-SM	5
		12
	SM	10
19.5'		13

TH

EL. 486.0'±

Depth	LOG	MC
		7
4.5'	CL	12
		14
9.0' W 10.5'	ML	16

TH

EL. 486.0'±

Depth	LOG	MC
		9
	SM	13
4.5'		14
		20
	SC	12
		14
11.0'		13
13.5'	SM-SC	14
16.5'	SM	13

NOTE:

1. SEE PLATE 19 FOR LOC
2. TH79-13 TO 24 WERE D DIAMETER BUCKET AU
3. SEE PLATE 36 FOR LE

SAFETY

TH 79-15

EL 486.0' ±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SM	3		NP	94	15		SILTY SAND: Tan to light brown
		7		NP	100	19	17	brown, medium dense
		8		NP	97	14	17	
10.5'		10		NP	89	16	18	red brown to brown, gravel to 3/4"
12.0'	SP/SM	5		NP	92	9	5	SAND-SILTY SAND: Brown, gravel to 3/4", loose
	SM	12		NP	95	22		SILTY SAND: Brown, gravel to 3/4"
		10		NP	97	35	23	dark brown to brown, cohesive, medium dense
19.5'		13		NP	98	22		dark brown to red brown

TH 79-16

EL 484.0' ±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SM	8		NP	92	37		SILTY SAND: Tan to brown, gravel to 3/4"
		12		NP	76	26		GRAVELLY SILTY SAND: Brown, gravel to 3", 10% cobbles to 6"
7.5'		11		NP	98	23		SILTY SAND: Medium dense, gravel to 3/8"
		6		NP	97	10		SAND-SILTY SAND: Brown, 5% cobbles to 6"
	SP/SM	5		NP	91	6		
		6		NP	95	8		
16.5'		6		NP	87	7	25	medium dense, gravel to 3"
19.5'	SM	10		NP	94	13		SILTY SAND: Brown to dark brown, gravel to 1 1/2"

TH 79-19

EL 486.0' ±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	CL	7	25	8	100	71		SANDY CLAY: Brown, cohesive, medium stiff
4.5'		12	23	8	100	71	5	
	ML	14	22	4	95	58	11	SANDY SILT: Dark brown, cohesive, medium dense, gravel to 3/4"
9.0' W 10.5'		18	19	2	96	59	11	

TH 79-20

EL 490.0' ±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
1.5'	SM	4	20	3	79	39		GRAVELLY SILTY SAND: Tan to light brown, gravel to 3"
4.5'	SC	9	26	12	90	45	26	CLAYEY SAND: Red brown, medium dense, cohesive, gravel to 1 1/2"
7.5'	SM	6		NP	73	18		SILTY GRAVELLY SAND: Light brown to brown, cohesive, gravel to 1 1/2", 10% cobbles to 9"
9.5' W	GP/GM	9		NP	54	8		SANDY GRAVEL-SILTY SANDY GRAVEL: Brown, gravel to 3", 10% cobbles to 9"

TH 79-23

EL 486.0' ±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SM	9		NP	84	21		GRAVELLY SILTY SAND: Dark brown to brown, gravel to 1 1/2", 10% cobbles to 6"
		13		NP	80	14	5	
4.5'		14	21	3	81	17	6	SILTY GRAVELLY SAND: Brown to gray, gravel to 3", loose, perched water at 4.5'
	SC	20	27	9	83	28		GRAVELLY CLAYEY SAND: Tan to brown, cohesive, gravel to 1 1/2", 10% cobbles to 6"
		12	28	8	81	25		
		14	32	10	93	29		CLAYEY SAND: Tan & brown, cohesive, and perched water
11.0'		13	33	12	92	31		
13.5'	SM/SC	14	29	6	86	20	40 60	GRAVELLY SILTY SAND-GRAVELLY CLAYEY SAND: Tan to brown, cohesive, gravel to 3", 5% cobbles to 12", dense to very dense
16.5'	SM	13		NP	92	20	60 60	SILTY SAND: Tan to brown, cohesive, gravel to 3/4", very dense

Test hole terminated at 19.5', due to bedrock

TH 79-24

EL 480.0' ±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SM	37		NP	91	34		SILTY SAND: Dark brown, cohesive, gravel to 1 1/2"
		15	24	3	93	27	7	brown, loose, 10% cobbles to 6"
6.0' W		15		NP	96	28	18	medium dense
		22		NP	95	30	17	brown to red brown
		42		NP	98	43	6	brown to gray, loose
		61	22	3	87	23		GRAVELLY SILTY SAND: Brown to gray, cohesive, gravel to 3", loose
		39	24	3	87	37	5	
		34		NP	83	37		
16.5'		36		NP	92	38	4	SILTY SAND: Brown to gray, cohesive, gravel to 1 1/2", loose
18.5'	ML		29	5	100	76	6	SANDY SILT: Black, cohesive, loose
19.5'	CL		28	8	100	88		SANDY CLAY: Black, cohesive
22.5'	ML		29	6	100	67	14	SANDY SILT: Dark brown to black, cohesive, medium dense
	SM			NP	100	34	4 5	SILTY SAND: Dark gray to black, cohesive loose
				NP	100	30		
				NP	100	41		
				NP	84	18		SILTY GRAVELLY SAND: Dark gray to black, cohesive, gravel to 1 1/2", 10% cobbles to 6"
30.0'				NP	87	30		GRAVELLY SILTY SAND: Dark gray to black, cohesive, gravel and cobbles to 1 1/2"
	ML		30	1	98	75	17	SANDY SILT: Gray, cohesive, medium dense
			43	16	100	84		
			48	13	100	82		
			48	11	100	84		
			30	1	100	91		SILT: Gray w/brown seams
50.0'			28	2	97	73		SANDY SILT: Gray, gravel to 1 1/2"

NOTE

1. SEE PLATE 19 FOR LOCATION OF BORINGS.
2. TH79-13 TO 24 WERE DRILLED WITH A 16 INCH DIAMETER BUCKET AUGER IN NOVEMBER 1979.
3. SEE PLATE 36 FOR LEGEND.

VERTICAL SCALE: 1 INCH = 5 FEET

SCALE 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.H. 79-13 THRU T.H. 79-24

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-___ B-___

DISTRICT FILE NO.

SHEET

PLATE B-37

2

T.T. 79-1

EL. 543.0'±	LOG	MC	LL	PI	-4	-200	N	
3.0'	CL	14	42	22	100	56		SANDY CLAY: Brown, cohesive
6.0'	SM	12		NP	100	33		SILTY SAND: Brown, cohesive
		16	27	5	99	64		SANDY SILT: Gray-brown, cohesive
	ML	23	34	10	100	82		brown-gold
15.0'		18	26	2	99	53		brown

T.T. 79-2

EL. 545.0'±	LOG	MC	LL	PI	-4	-200	N	
3.0'	CL	14	32	14	99	77		SANDY CLAY: Golden brown, cohesive
6.0'	SM	16	33	9	97	41		SILTY SAND: Tan, brown w/gray, some cohesion, cemented sand and gravel to 5/8"
9.0'	ML	18	24	1	98	63		SANDY SILT: Tan & brown, cohesive, cemented sand
12.0'	SP	4		NP	60	3		GRAVELLY SAND: Tan, gravel to 3/4"
15.0'	SM	17	25	1	88	43		SILTY SAND: Brown & gray, cohesive

EL. 550.0'±	LOG	MC	LL	PI	-4	-2
		13	36	15	100	8
6.0'	CL	12	33	11	100	5
9.0'	SM	13	24	2	100	4
12.0'	SC	15	30	12	100	4
15.0'	SP-SM	3		NP	100	

T.T. 79-5

EL. 532.0'±	LOG	MC	LL	PI	-4	-200	N	
3.0'	ML	11	23	4	99	78		SANDY SILT: Dark brown, cohesive
		11	28	12	98	73		SANDY CLAY: Dark brown, cohesive
9.0'	CL	11	28	10	99	58		
12.0'	ML-CL	16	29	7	100	80		SANDY SILT-SANDY CLAY: Brown, cohesive
15.0'	SM	8		NP	84	18		GRAVELLY SILTY SAND: Light brown, some cohesion, gravel to 1 1/2"

T.T. 79-6

EL. 515.0'±	LOG	MC	LL	PI	-4	-200	N	
		10	22	1	89	56		SANDY SILT: Dark brown, cohesive, gravel to 3/4"
6.0'	ML	11	22	2	93	52		brown
		12	22	1	82	39		GRAVELLY SILTY SAND: Brown & gold, cohesive, gravel to 3/4"
	SM	10	23	4	90	34		SILTY SAND: Dark brown, some cohesion, gravel to 1/2"
15.0'		8		NP	60	17		SILTY GRAVELLY SAND: Light brown, some cohesion, 2% cobbles to 5"

EL. 535.0'±	LOG	MC	LL	PI	-4	-2
3.0'	ML-CL	11	24	7	99	5
		9		NP	95	2
9.0'	SM	10	24	4	95	4
12.0'	SP	5		NP	71	
15.0'	SP-SM	5		NP	79	

T.T. 79-9

EL. 543.0'±	LOG	MC	LL	PI	-4	-200	N	
3.0'	ML	16	22	1	100	77		SANDY SILT: Dark brown, cohesive
		16	33	9	96	63		SANDY CLAY: Camel brown, gravel to 3/4"
9.0'	CL	19	29	8	99	65		light brown, cohesive
12.0'	[illegible]	9		NP	73	10		GRAVELLY SAND-SILTY GRAVELLY SAND: Light brown, 8% cobbles to 4"
15.0'	SM	8		NP	86	14		SILTY GRAVELLY SAND: Brown, 15% cobbles to 4"

T.T. 79-11

EL. 546.0'±	LOG	MC	LL	PI	-4	-200	N	
3.0'	CL	8	36	14	94	58		SANDY CLAY: Red-brown, cohesive
6.0'	SC	7	37	15	79	31		GRAVELLY CLAYEY SAND: Red-brown, cohesive, gravel to 1 1/2"
9.0'	SM	13	24	4	99	48		SILTY SAND: Light brown, cohesive
12.0'	SP	6		NP	99	4		SAND: Light brown
15.0'	SM	8	22	1	94	41		SILTY SAND: Light brown, very little cohesion, gravel to 3/4"

552.0'±	LOG	MC	LL	PI	-4	-2
3.0'	CL	9	32	18	100	
6.0'	ML	12	46	20	100	
9.0'	SM	5		NP	99	
12.0'	SC	7	29	8	99	
15.0'	SM	8	25	2	96	

E ENGINEERING PAYS

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T.T. 79-3

EL. 550.0'±	LOG	MC	LL	PI	-4	-200	N	
	CL	13	36	15	100	82		SANDY CLAY: Reddish brown, cohesive
6.0'		12	33	11	100	51		brown
9.0'	SM	13	24	2	100	41		SILTY SAND: Light brown, some cohesion
12.0'	SC	15	30	12	100	47		CLAYEY SAND: Brown w/bits of gray, some cohesion
15.0'	SP-SM	3		NP	100	6		SAND-SILTY SAND: Light brown, some cohesion

T.T. 79-4

549.0'±	LOG	MC	LL	PI	-4	-200	N	
3.0'	CL	14	36	18	99	66		SANDY CLAY: Reddish brown, cohesive
6.0'	ML	12	28	5	98	56		SANDY SILT: Brown, some cohesion
9.0'	SM	6		NP	90	21		SILTY SAND: Brown w/red, some cohesion
12.0'	SP-SM	4		NP	72	7		GRAVELLY SAND-SILTY GRAVELLY SAND: Tan, gravel to 1 1/2"
15.0'	SP	4		NP	56	1		GRAVELLY SAND: Tan, gravel to 1 1/2"

T.T. 79-7

EL. 535.0'±	LOG	MC	LL	PI	-4	-200	N	
3.0'	ML-CL	11	24	7	99	58		SANDY SILT-SANDY CLAY: Brown, cohesive, gravel to 3/8"
	SM	9		NP	95	25		SILTY SAND: Light brown, cohesive, gravel to 3/4"
9.0'		10	24	4	95	40		
12.0'	SP	5		NP	71	3		GRAVELLY SAND: Light brown, gravel to 3"
15.0'	SP-SM	5		NP	79	11		GRAVELLY SAND-SILTY GRAVELLY SAND: Light brown, gravel to 1 1/2"

T.T. 79-8

EL. 532.0'±	LOG	MC	LL	PI	-4	-200	N	
3.0'	CL	16	36	17	100	86		FAT CLAY: Golden brown, cohesive
6.0'	SM	11	28	4	77	39		GRAVELLY SILTY SAND: Brown-tan, cohesive, 5% cobbles to 4"
9.0'	ML-CL	12	27	7	80	53		GRAVELLY SANDY SILT-GRAVELLY SANDY CLAY: Dark brown, cohesive, 10-20% cobbles to 4"
	SP	5		NP	75	1		GRAVELLY SAND: Brown, 5% cobbles to 4"
15.0'		6		NP	83	2		tan-brown, gravel to 1 1/2"

NOTE:

1. SEE PLATE 17 FOR LOCACATION OF TRENCHES.
2. TT79-1 TO 9 AND TT79-11 AND 12 WERE EXCAVATED WITH A BACKHOE IN NOVEMBER 1979.
3. SEE PLATE 36 FOR LEGEND.

T.T. 79-12

552.0'±	LOG	MC	LL	PI	-4	-200	N	
3.0'	CL	9	32	18	100	86		FAT CLAY: Light brown, cohesive, some organics
6.0'	ML	12	46	20	100	90		SILT: Brown, cohesive
9.0'	SM	5		NP	99	15		SILTY SAND: Brown, some cohesion
12.0'	SC	7	29	8	99	34		CLAYEY SAND: Brown, cohesive
15.0'	SM	8	25	2	96	42		SILTY SAND: Light brown, cohesive

VERTICAL SCALE: 1 INCH = 5 FEET

SCALE FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.T. 79-1 THRU T.T. 79-9
T.T. 79-11, T.T. 79-12

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE [illegible]

SAFETY PAYS

1

2

TT 79-10

EL-595'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SP	3		NP	95	1		SAND: Light brown & gold, gravel to 1 1/2"
6.0'		6		NP	87	1		
9.0'	SM	11	27	2	89	29		SILTY SAND: Brown & gray, cohesive, gravel to 1 1/2"
12.0'	SP	2		NP	91	1		SAND: Tan-brown, gravel to 1 1/2"
15.0'	SW / SM	5		NP	76	7		GRAVELLY SAND-SILTY GRAVELLY SAND: Tan-brown, 5% cobbles to 5"

TT 79-13

EL-504'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
1.0'	SM	16	31	7	99	28		SILTY SAND: Brown, some cohesion, organics
3.0'	ML	23	37	9	98	56		SANDY SILT: Dark brown, cohesive, organics
6.0'	SM / SC	24	28	7	84	36		GRAVELLY SILTY SAND-GRAVELLY CLAYEY SAND: Dark brown, cohesive, organics
9.0'	CL	26	29	9	98	71		SANDY CLAY: Dark brown, cohesive, organics

TT 79-14

EL.515±	LOG	MC	LL	PI	-4
3.0'	SP	2		NP	81
6.0'	SM	11	41	14	95
9.0'	SP	9		NP	69
12.0'	SM	11		NP	67
14.0' W	SP	17		NP	7

TT 79-16

EL.507'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	ML	14	34	4	97	61		SANDY SILT: Brown, cohesive, gravel to 3/4"
6.0'	CL	24	30	8	97	59		SANDY CLAY: Brown, cohesive, organics (roots from bushes)
7.0' W	SM / SC	21	27	7	89	35		SILTY SAND-CLAYEY SAND: Brown, cohesive, organics

TT 79-17

EL-504'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	CL	21	36	14	98	81		SANDY CLAY: Brown, cohesive
5.0' W		27	31	11	100	85		FAT CLAY: Dark brown, cohesive, organics

TT 79-18

EL.553'±	LOG	MC	LL	PI	-4
3.0'	CL	8	38	24	89
	SP / SM	6		NP	98
9.0'		7		NP	96
	SP	2		NP	9
15.0'		3		NP	5

TT 79-20

EL.540'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	SM	8	28	5	93	43		SILTY SAND: Light brown, cohesive, gravel to 3/8"
6.0'	SC	13	30	8	100	49		CLAYEY SAND: Light brown, cohesive
	SM	9	26	3	93	47		SILTY SAND: Brown, cohesive, gravel to 3/4"
12.0'		10	24	2	100	37		
15.0'	SP / SM	12		NP	58	9		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, very little cohesion, gravel to 3"

TT 79-21

EL-540'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SM	6	21	1	95	44		SILTY SAND: Brown, cohesive, gravel to 1 1/2"
6.0'		9		NP	80	27		GRAVELLY SILTY SAND: Light brown, cohesive, gravel to 3"
9.0'	SW	3		NP	87	2		SAND: Brown, gravel to 3/4", 1-12" cobble
	SP	2		NP	72	2		GRAVELLY SAND: Brown, gravel to 3"
15.0'		2		NP	62	0		

TT 79-22

EL.532'±	LOG	MC	LL	PI	-4
	ML	5	19	1	9
6.0'		8	22	1	9
	SM	5	24	2	9
12.0'		12		NP	9
15.0'	SP	2		NP	6

ENGINEERING PAYS

...wn, organics
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...AYEY SAND:
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..., organics
...gravel
...own,
...1-12" cobble
...to 3"

TT 79-14

EL. 545'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	SP	2		NP	81	2		GRAVELLY SAND: Light brown, gravel to 1 1/2"
6.0'	SM	11	41	14	95	39		SILTY SAND: Brown, cohesive, gravel to 3/4"
9.0'	SP	9		NP	69	1		GRAVELLY SAND: Red brown, gravel to 3"
12.0'	SM	11		NP	67	13		SILTY GRAVELLY SAND: Red-brown, some cohesion, gravel to 3"
14.0' W	SP	17		NP	73	2		GRAVELLY SAND: Red-brown, gravel to 3"

TT 79-15

EL. 565'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	SW / SM	2		NP	81	6		GRAVELLY SAND-SILTY GRAVELLY SAND: Light brown, gravel to 1 1/2"
6.0'	SM	10	22	2	92	29		SILTY SAND: Brown, cohesive, gravel to 3/4"
7.0' W	SW / SM	12		NP	88	10		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown

TT 79-18

EL. 553'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	CL	8	38	24	89	55		SANDY CLAY: Light brown, cohesive, gravel to 3"
	SP / SM	6		NP	98	11		SAND-SILTY SAND: Light brown, very little cohesion
9.0'		7		NP	96	8		
	SP	2		NP	93	0		SAND: Brown, gravel to 1 1/2"
15.0'		3		NP	59	1		GRAVELLY SAND: Brown, gravel to 1 1/2"

TT 79-19

EL. 555'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SC	7	33	13	89	38		CLAYEY SAND: Light brown, cohesive gravel to 3/4"
6.0'		6	29	8	95	27		little cohesion
9.0'	SP	5		NP	82	2		GRAVELLY SAND: Brown, gravel to 1 1/2"
12.0'	SM	9	23	1	96	35		SILTY SAND: Brown, cohesive, gravel to 3/4"
15.0'	SM / SC	15	27	6	97	45		SILTY SAND-CLAYEY SAND: Brown, cohesive

TT 79-22

EL. 532'±	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	ML	5	19	1	95	66		SANDY SILT: Brown, cohesive, gravel to 3/8"
6.0'		8	22	1	99	60		
	SM	5	24	2	97	28		SILTY SAND: Brown, cohesive, gravel to 3/4"
12.0'		12		NP	93	27		gravel to 1 1/2"
15.0'	SP	2		NP	67	3		GRAVELLY SAND: Brown, gravel to 3"

NOTE:
1. See plate 19 for location of Test Trenches.
2. TT 79-10 & 79-13 to 22 were excavated in November 1979 with a backhoe
3. See plate 36 for legend.

VERTICAL SCALE: 1 INCH = 5 FEET
SCALE 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
T.T. 79-10, T.T. 79-13 THRU T.T. 79-22

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW 09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-30

SAFETY PAYS

2

TH 80-1

EL. 557'		MC	LL	PI	-4	-200	N	
	CL	14	43	23	100	85		SANDY CLAY, brown, very stiff, roots in top 6", cohesive
		18	41	20	100	88	24	
		12	32	12	99	90	23	light brown, less cohesive
10.0'		4	29	16	98	53	28	
11.5'	GM	4		NP	66	35	R	SANDY SILTY GRAVEL, light brown, moderately cohesive
14.0'	ML	6		NP	97	53		SANDY SILT, light brown, moderately cohesive
	CL	12	32	12	100	73	55	SANDY CLAY, brown, hard, moderately cohesive, iron stained
18.0'		11	35	12	94	82	60+	light grey-brown, less cohesive
19.5'	ML	8		NP	93	61		SANDY SILT, light yellow-brown, 1-6" cobble
23.0'	SM	4		NP	88	17	60+	SILTY SAND, light brown, very dense, noncohesive, gravel to 2"
26.0'	SW-SM	2		NP	78	12	R	GRAVELLY SAND-SILTY GRAVELLY SAND, light brown, very dense, noncohesive, gravel to 3", some caving
28.0'	SP-SM	2		NP	74	9	R	
30.0'	SM	6		NP	78	32	31	GRAVELLY SILTY SAND, brown, dense, moderately cohesive
31.5'	SC	15	27	13	79	35		GRAVELLY CLAYEY SAND, brown, cohesive
	SW-SM	4		NP	88	7	R	SAND-SILTY SAND, brown, noncohesive, gravel to 1 1/2"
37.0'		4		NP	87	9	R	gravel to 2"
39.0'	SC	19	32	12	85	48	R	GRAVELLY CLAYEY SAND, dark brown, cohesive, gravel to 2"
W 40.0' 41.0'	SW-SM	6		NP	55	10		GRAVELLY SAND-SILTY GRAVELLY SAND, brown, noncohesive, gravel to 3", groundwater at 40.0', caving

TH 80-2

EL 530'		MC	LL	PI	-4	-200	N	
2.0'	ML	10		NP	94	61		SANDY SILT, dark brown, roots in top 6"
	SC	10	33	17	85	27	11	GRAVELLY CLAYEY SAND, dark brown, medium dense, cobbles to 4", barely cohesive
7.5'		9	32	16	62	17	R	CLAYEY GRAVELLY SAND, dark brown, gravel to 2", barely cohesive
	SM	9		NP	69	16	R	SILTY GRAVELLY SAND, dark brown, gravel to 2", barely cohesive
12.0'		14		NP	97	17	R	SILTY SAND, red-brown, moderately cohesive
	SW-SM	11		NP	96	10	60+	SAND-SILTY SAND, red-brown, noncohesive
17.0'		8		NP	90	7		

EL 542'		MC	LL	PI
4.0'	SM	6		NP
5.0'	CH	24	74	50
6.5'	CL	6	48	28
7.5'	MH	27	56	25
10.5'	SM	9		NP
11.5'	SW-SM	4		NP
14.0'	SW-SC	5	25	8
15.5'	SP-SM	6		NP
		20		NP
19.0'	SW-SM	6		NP
20.0'	CH	28	53	26
	SW-SM	4		NP
		4		NP
27.0'		4		NP
	SM	10		NP
		6		NP
W 34.0'		6		NP

TH 80-5

EL 550'		MC	LL	PI	-4	-200	N	
2.0'	ML-CL	6	22	6	99	69		SANDY SILTY-SANDY CLAY, brown, moderately cohesive, roots in top 6"
4.5'	CL	8	26	15	99	56	49	SANDY CLAY, brown, hard, moderately cohesive
7.0'	SW-SM	13		NP	73	9	60+	GRAVELLY SAND-SILTY GRAVELLY SAND, tan, very dense, cohesive
8.0'	CL	9	30	11	100	88		SANDY CLAY, tan, moderately cohesive
9.0'	ML	4		NP	98	59	53	SANDY SILTY, tan, very dense, noncohesive
	SM	14		NP	98	21		SILTY SAND, brown, dense, moderately cohesive, lenses of gray cohesive silt to 6" thick
13.5'		14		NP	89	30	41	
16.0'	ML-CL	3	27	5	97	62	R	SANDY SILT-SANDY CLAY, grey-brown, noncohesive, gravel to 3"
18.0'	SP-SM	3		NP	56	8	R	GRAVELLY SAND-SILTY GRAVELLY SAND, grey-brown, noncohesive, gravel to 3"
	SW-SM	3		NP	85	8		caving
		2		NP	85	7	R	
		6		NP	84	12		brown, barely cohesive
25.5'		3		NP	74	10	R	light brown, noncohesive
27.5'	SC	12	30	12	74	29	R	GRAVELLY CLAYEY SAND, light brown, noncohesive, 5% cobbles to 5", lenses of sandy clay to 6" thick
30.0'	SP-SM	3		NP	91	5	R	GRAVELLY SAND-SILTY GRAVELLY SAND, gray-brown, noncohesive, gravel to 3", caving
32.0'	SW-SM	3		NP	94	6		SAND-SILTY SAND, gray-brown, noncohesive, gravel to 3"
35.0'	SM	22		NP	91	45	R	SILTY SAND, light brown, lenses of brown sandy silt and yellow medium-grained sand
37.0'	SM-SC	11	26	6	82	21	R	GRAVELLY SILTY SAND-GRAVELLY CLAYEY SAND, light brown, moderately cohesive
W 37.5' 39.0'	SW-SM	5		NP	82	5	R	GRAVELLY SAND-SILTY GRAVELLY SAND, gray-brown, noncohesive, groundwater at 37.5'

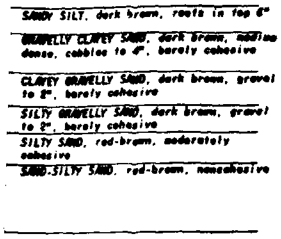
TH 80-6

EL 548'		MC	LL	PI	-4	-200	N	
1.5'	ML	7		NP	99	69		SANDY SILT, red-brown, moderately cohesive, roots in top 6"
4.0'	CL	12	45	28	100	78	60+	SANDY CLAY, red-brown, hard, cohesive
6.0'	SC	7	25	8	96	37	12	CLAYEY SAND, red-brown, medium dense, moderately cohesive
8.0'	SM	4		NP	100	18		SILTY SAND, yellow-brown, noncohesive caving
9.5'	ML			NP	97	58	5	SANDY SILTY, yellow-brown, loose, noncohesive
	CL	26	41	19	100	80	30	SANDY CLAY, gray with yellow sand, very stiff, moderately cohesive
		25	36	15	99	73		
16.0'		17	38	18	100	66	20	
17.0'	SM	9		NP	98	27		SILTY SAND, yellow-brown, noncohesive
19.0'	SW-SM	6		NP	73	11	R	GRAVELLY SAND-SILTY GRAVELLY SAND, red-brown, moderately cohesive, gravel to 1"
21.0'	SC	17	34	16	71	33	R	GRAVELLY CLAYEY SAND, brown, rust stained, moderately cohesive, 5% cobbles to 4"
23.0'	SM	3		NP	71	24		SILTY GRAVELLY SAND, brown, noncohesive, gravel to 3"
	SC	11	26	13	80	23	R	GRAVELLY CLAYEY SAND, brown, noncohesive, gravel to 3"
28.0'		18	28	16	82	26	21	gray & yellow, moderately cohesive
31.0'	SW-SM	4		NP	71	9	R	GRAVELLY SAND-SILTY GRAVELLY SAND, gray, noncohesive, gravel to 3"
34.0'	SM	5		NP	75	13	R	SILTY GRAVELLY SAND, gray, lenses of brown silt, 1-6" cobble

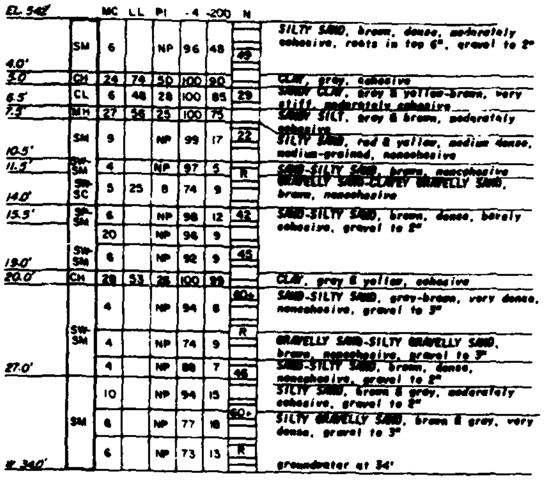
EL 555'		MC	LL	PI
2.5'	ML-CL	9	23	6
	CL	8	28	11
5.0'		9	29	12
7.0'	ML	9	29	5
	CL	36	29	0
10.5'		19	34	[illegible]
12.5'	SM	10		NP
	SW-SM	3		NP
17.0'		4		NP
18.5'	SP-SM	4		NP
21.0'	SM	4		NP
24.0'	SP-SM	3		NP
25.5'	SC	19	30	8
27.5'	SP	3		NP
	SW-SM	3		NP
		2		NP
		3		NP
		4		NP
W 40.0'		9		NP

/ALUE ENGINEERING PAYS

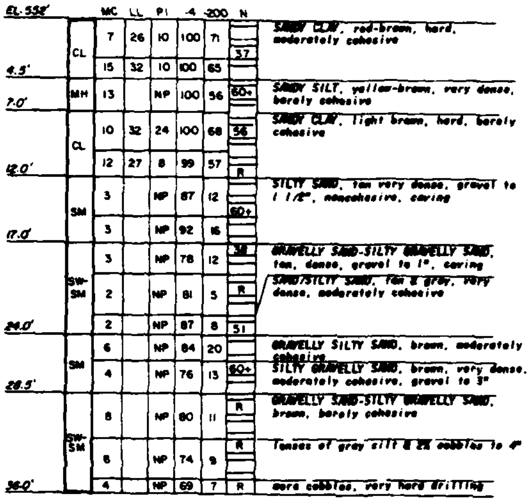
2



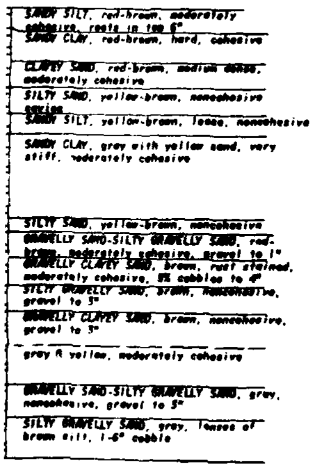
TH 80-3



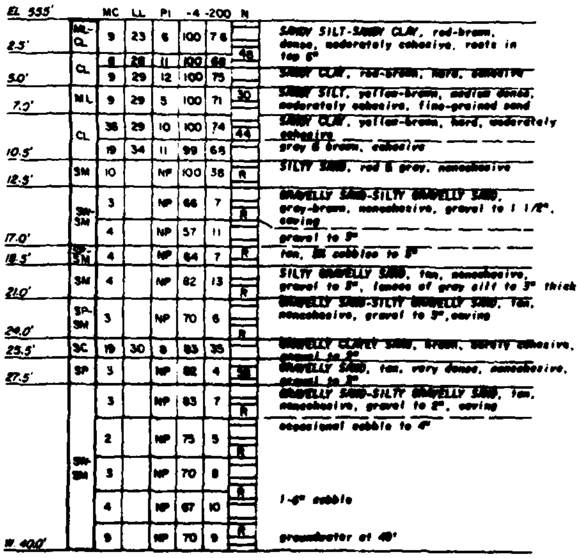
TH 80-4



-6



TH 80-7



NOTE:

1. See plate 17 for location of borings.
2. TH 80-1 to 7 were drilled in April 1980 with a 16-inch diameter bucket auger
3. See plate 36 for legend

VERTICAL SCALE: 1 INCH = 5 FEET

SCALE 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
TH 80-1 THRU TH 80-7

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET

PLATE B-40

SAFETY PAYS

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TH 80-8

EL. 556'		MC	LL	PI	-4	-200	N	
	CL	10	33	15	99	64	54	SANDY CLAY, brown, hard, moderately cohesive
		11	31	13	100	75	30	yellow-brown, very stiff
		17	34	13	99	75		gray & yellow, cohesive, hard
10.0'		16	30	8	99	72	38	
	SM	11	27	4	95	37	38	SILTY SAND, yellow-brown, dense, moderately cohesive
13.5'		10		NP	97	35		brown, barely cohesive
15.5'	SW-SM	7		NP	96	11	50	SAND-SILTY SAND, light brown, dense, noncohesive
17.0'	SM	9		NP	80	18		SILTY GRAVELLY SAND, light brown, moderately cohesive, gravel to 1 1/2"
19.5'	SW-SM	3		NP	70	5	R	GRAVELLY SAND-SILTY GRAVELLY SAND, tan, noncohesive, gravel to 3", hard drilling, caving
20.5'	SM	9		NP	78	19	R	SILTY GRAVELLY SAND, tan, noncohesive
	SW-SM	3		NP	55	5		GRAVELLY SAND-SILTY GRAVELLY SAND, yellow & red, noncohesive, gravel to 3", caving
26.0'		5		NP	62	9	R	tan, lenses of gray cohesive silt to 2"
30.0'	SP-SM	3		NP	70	7	R R	occasional cobble to 5", lenses of brown silty sand to 4"
33.0'	SW-SM	4		NP	77	6	R	5% cobbles to 6", caving
35.0'	SP-SM	4		NP	64	7		
37.5'	SW-SM	4		NP	73	7	R	

TH 80-9

EL. 544'		MC	LL	PI	-4	-200	N	
1.5'	SW-SC	5	25	7	84	46		GRAVELLY SILTY SAND-GRAVELLY CLAYEY SAND, light brown, barely cohesive, gravel to 2"
	SC	7	49	32	75	16	R	CLAYEY GRAVELLY SAND, red, cohesive, gravel to 3"
		7	44	26	78	18	R	brown, barely cohesive, 5% cobbles to 4"
7.5'		7	38	22	79	14		gravel to 3", moderately cohesive
9.5'	SW-SC	8	37	17	69	12	R	GRAVELLY SAND-CLAYEY GRAVELLY SAND, brown, moderately cohesive, gravel to 3"
12.0'	SP-SC	6	33	15	53	6	R	
	SW-SC	10	40	24	65	11		red-brown
15.0'		8	31	10	78	8	R	1-5" cobble
18.0'	SW-SM	7	23	4	60	11	R	GRAVELLY SAND-SILTY GRAVELLY SAND, brown barely cohesive, gravel to 3"
22.0'	SM	12	29	6	75	19	R	SILTY GRAVELLY SAND-light brown, moderately cohesive, gravel to 3"
24.0'	SW-SM	5		NP	64	7	R	GRAVELLY SAND-SILTY GRAVELLY SAND, light brown, barely cohesive, gravel to 3", cobbles at 24', very hard drilling

TH 80-10

EL. 550'		MC	LL	PI	-4	-200	N
	CL	10	40	21	99	61	
3.5'		10	36	18	100	73	60+
	SM	8		NP	100	48	53
		7		NP	100	39	
		17		NP	99	34	40
12.0'		5		NP	83	13	35
	SW-SM	3		NP	64	6	
17.0'		4		NP	77	11	R
	SM	16		NP	90	36	R
22.0'		7		NP	64	22	R
	SP-SM	4		NP	55	11	R
		3		NP	58	7	R
29.0'		3		NP	51	6	

TH 80-12

EL. 536'		MC	LL	PI	-4	-200	N	
	CL	9	32	15	100	76	45	SANDY CLAY, brown, hard, moderately cohesive, occasional gravel to 2"
4.5'		9	29	12	100	57		yellow-brown, barely cohesive
6.5'	SC	4	26	14	59	17	R	CLAYEY GRAVELLY SAND, tan, noncohesive 15% cobbles to 4"
9.0'	GP-GM	3	20	6	43	6	R	SANDY GRAVEL-SILTY SANDY GRAVEL, tan, noncohesive, 20% cobbles to 5", caving
12.0'	GM	5		NP	56	14	R	SILTY SANDY GRAVEL, tan, noncohesive, 10% cobbles to 6", lenses of cohesive silty sand to 5"
13.0'	SW-SM	6	23	6	72	12		GRAVELLY SAND-SILTY GRAVELLY SAND, tan, noncohesive, 5% cobbles to 4"
14.0'	SC	19	32	13	84	33		GRAVELLY CLAYEY SAND, brown, cohesive
16.0'	SW-SM	4		NP	82	5	R	GRAVELLY SAND-SILTY GRAVELLY SAND, tan, noncohesive, occasional cobble to 4"
	SP	4		NP	83	4	R	GRAVELLY SAND, tan, noncohesive, gravel to 3"
22.0'		3		NP	58	4	R	occasional cobble to 5", caving
24.0'	SP-SM	3		NP	67	5	R	GRAVELLY SAND-SILTY GRAVELLY SAND, tan, noncohesive, occasional cobble to 5", caving
25.0'	[illegible]	14		NP	62	12		groundwater at 25'

TH 80-13

EL. 537		MC	LL	PI	-4	-200	N	
3.5'	ML	10	34	3	99	79	60+	SANDY SILT, brown, very dense, moderately cohesive
5.0'	CL	11	28	8	100	79		SANDY CLAY, yellow-brown, barely cohesive
8.0'	GP-GM	3		NP	52	7	R	SANDY GRAVEL-SILTY SANDY GRAVEL, light brown, noncohesive, 15% cobbles to 5", hard drilling
10.0'	SP-SM	3		NP	57	6	R	GRAVELLY SAND-SILTY GRAVELLY SAND, light brown, noncohesive, 10% cobbles to 4"
12.0'	SW-SM	3		NP	63	5	R	tan, 5% cobbles to 4", caving
15.0'	SP	4		NP	58	4	R	GRAVELLY SAND, tan, noncohesive, 5% cobbles to 4", caving
18.0'	SW-SM	5		NP	81	7	R	GRAVELLY SAND-SILTY GRAVELLY SAND, tan, noncohesive, 5% cobbles to 4", 1-9" cobble
20.5'	SP-SM	4		NP	65	5	R	3% cobbles to 4", caving badly
22.0'	SW	4		NP	76	4		GRAVELLY SAND, tan, noncohesive, gravel to 3"
24.0'	SP	4		NP	94	4	R	SAND, tan, noncohesive, gravel to 2"
26.0'	SP-SM	4		NP	89	5		SAND-SILTY SAND, tan, noncohesive, occasional cobble to 4", groundwater at 25.5'

TH 80-14

EL. 536'		MC	LL	PI	-4	-200	N
1.5'	ML-CL	6	25	7	86	55	
4.0'	SM-SC	9	28	7	84	18	
6.0'	SW-SM	6		NP	65	9	
9.0'	GP-GC	5	27	10	49	10	
12.0'	GP-GM	5		NP	48	8	
15.0'	SM	5		NP	72	23	
	SW-SM	6		NP	78	6	
20.0'		5		NP	72	9	
	SP-SM	4		NP	60	6	
25.0'		6		NP	75	5	
27.0'	SW-SM	6		NP	79	9	

ND-GRAVELLY CLAYEY SAND,
ly cohesive, gravel to 2"
SAND, red, cohesive,
esive, 5% cobbles to 4"
derately cohesive
YEY GRAVELLY SAND, brown,
ve, gravel to 3"

TY GRAVELLY SAND, brown
gravel to 3"
ND-light brown, moderately
to 3"
TY GRAVELLY SAND, light
esive, gravel to 3",
very hard drilling

TH 80-10

EL. 550'		MC	LL	PI	-4	-200	N	
	CL	10	40	21	99	61		SANDY CLAY, red-brown, hard, moderately cohesive, gravel to 1"
3.5'		10	36	18	100	73	60+	
	SM	6		NP	100	46	53	SILTY SAND, gray & brown, very dense, barely cohesive, fine-grained sand
		7		NP	100	39		gray & red
		17		NP	99	34	40	dense, thin lenses of gray silt
12.0'		5		NP	83	13	35	SILTY GRAVELLY SAND, gray, dense, noncohesive, medium-grained, gravel to 2"
	SW-SM	3		NP	84	6		GRAVELLY SAND-SILTY GRAVELLY SAND, tan noncohesive, gravel to 3", caving
17.0'		4		NP	77	11	R	occasional cobble to 4"
	SM	16		NP	90	36	R	SILTY SAND, red & gray, moderately cohesive
22.0'		7		NP	64	22	R	SILTY GRAVELLY SAND, gray-brown, barely cohesive, gravel to 3"
	SP-SM	4		NP	55	11	R	GRAVELLY SAND-SILTY GRAVELLY SAND, light brown, noncohesive, 5% cobbles to 4"
		3		NP	58	7	R	1-8" cobble at 26', caving
29.0'		3		NP	51	6		stopped drilling due to caving

TH 80-11

EL. 545'		MC	LL	PI	-4	-200	N	
2.0'	ML-CL	7	23	7	85	51		GRAVELLY SANDY SILT-GRAVELLY SANDY CLAY, brown, moderately cohesive, gravel to 3"
4.0'	SC	6	38	21	86	16	R	CLAYEY SAND, red-brown, cohesive, gravel to 2"
6.0'	SW-SC	6	28	13	86	12	R	SAND-CLAYEY SAND, red-brown, noncohesive, gravel to 3"
10.5'	SW-SM	6		NP	80	9	R	GRAVELLY SAND-SILTY GRAVELLY SAND, red-brown, noncohesive, gravel to 3"
12.0	CL	9	33	11	97	64	60+	SANDY CLAY, gray & red, hard, moderately cohesive
13.5'	SW-SM	8		NP	83	9		GRAVELLY SAND-SILTY GRAVELLY SAND, red, noncohesive
15.5'	SM	8		NP	75	14	R	SILTY GRAVELLY SAND, gray & red, gravel to 3"
	SW-SM	6		NP	68	6		GRAVELLY SAND-SILTY GRAVELLY SAND, light brown, noncohesive, 5% cobbles to 4"
		4		NP	80	9	R	
22.0'		4		NP	74	6	R	1-6" cobble
25.0'	SC	5	28	7	75	13	R	CLAYEY GRAVELLY SAND, light brown, moderately cohesive, occasional cobble to 4"
	SW-SM	4		NP	71	11	R	GRAVELLY SAND-SILTY GRAVELLY SAND, light brown, barely cohesive, occasional cobble to 8", caving
		4		NP	76	7	R	tan, noncohesive, gravel to 3", occasional cobble to 7"
34.0'		4		NP	70	7	R	10% cobbles to 6" below 32'

n, very dense,
ive
ow-brown, barely
TY SANDY GRAVEL,
cohesive, 15% cobbles
ling
LTY GRAVELLY SAND,
cohesive, 10% cobbles to 4"
to 4", caving
an, noncohesive, 5%
aving
LTY GRAVELLY SAND, tan,
cobbles to 4", 1-9" cobble
, caving badly
an, noncohesive, gravel
hesive, gravel to 2"
- tan, noncohesive,
e to 4", groundwater

TH 80-14

EL 536		MC	LL	PI	-4	-200	N	
1.5'	ML-CL	6	25	7	86	55		SANDY SILT-SANDY CLAY, brown, medium dense, moderately cohesive
4.0'	SM-SC	9	28	7	84	18		GRAVELLY SILTY SAND-GRAVELLY CLAYEY SAND, red-brown, dense, moderately cohesive
6.0'	SW-SM	6		NP	65	9		GRAVELLY SAND-SILTY GRAVELLY SAND, brown, medium dense, noncohesive, gravel to 3"
9.0'	GP-GC	5	27	10	49	10		SANDY GRAVEL-CLAYEY SANDY GRAVEL, brown, hard drilling, noncohesive, 5% cobbles to 4"
12.0'	GP-GM	5		NP	48	8		SANDY GRAVEL-SILTY SANDY GRAVEL, brown, noncohesive, 5% cobbles to 4"
15.0'	SM	5		NP	72	23		SILTY GRAVELLY SAND, brown, noncohesive
	SW-SM	6		NP	78	6		GRAVELLY SAND-SILTY GRAVELLY SAND, tan, noncohesive, gravel to 2"
20.0'		5		NP	72	9		caving, occasional cobble to 4"
	SP-SM	4		NP	60	6		no cobbles
25.0'		6		NP	75	5		
27.0'	SW-SM	6		NP	79	9		gravel to 3"

NOTE:

1. See plate 19 for location of borings
2. TH 80-8 to 14 were drilled in April 1980 with a 16-inch diameter bucket auger
3. See plate 36 for legend

VERTICAL SCALE: 1 INCH = 8 FEET

SCALE 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS

TH 80-8 THRU TH 80-14

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-____
DISTRICT FILE NO.
SHEET

TH 80-15

EL. 576'	LOG	MC	LL	PI	-4	-200	N	
2.0'	ML-CL	5	21	7	99	77		SANDY SILT-SANDY CLAY: Brown, medium dense, moderately cohesive, 1-6" cobble.
	CL	16	38	14	100	78		SANDY CLAY: Red-brown, dense, cohesive
7.5'		16	36	12	100	61		tan, less cohesive.
9.0'	SM	8		NP	100	46		SILTY SAND: Tan, medium dense, moderately cohesive.
12.0'	GM	4		NP	34	14		SILTY SANDY GRAVEL: Tan, noncohesive, gravel to 3", caving badly.
15.0'	SW-SM	2		NP	72	11		GRAVELLY SAND-SILTY GRAVELLY SAND: Tan, noncohesive, gravel to 3", caving badly.
17.0'	SP	1		NP	84	4		GRAVELLY SAND: Tan, noncohesive, gravel to 3", caving badly.

TH 80-16

EL. 531'	LOG	MC	LL	PI	-4	-200	N	
2.0'	SW-SC	2	22	4	78	9		SILTY GRAVELLY SAND-CLAYEY GRAVELLY SAND: Brown, noncohesive, 10% cobbles to 4"
	SC	19	25	11	76	19		CLAYEY GRAVELLY SAND: Brown, moderately cohesive, gravel to 2"
7.0'		15	25	8	91	42		CLAYEY SAND: Brown, moderately cohesive, gravel to 3"
10.0'	SM	9		NP	96	17		SILTY SAND: Light-brown, noncohesive, gravel to 3"
12.0'	SW-SM	8		NP	90	12		SAND-SILTY SAND: Light-brown, noncohesive, gravel to 3"
	SP-SM	10		NP	97	7		finer-grained sand
15.5'		7		NP	[illegible]	6		GRAVELLY SAND-SILTY GRAVELLY SAND: Tan, noncohesive, 5% cobbles to 5".
	GP	4		NP	48	4		SANDY GRAVEL: Tan, noncohesive, 5% cobbles to 5"
20.0'		4		NP	51	4		light-brown, 10% cobbles to 6"
	SP-SM	5		NP	54	7		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, noncohesive, 10% cobbles to 6"
25.0'		6		NP	57	10		5% cobbles to 4"
W 27.0'	SM	7		NP	60	13		SILTY GRAVELLY SAND: Brown, noncohesive, 5% cobbles to 4", 1-9" cobble.
29.0'	GP-GM			NP	53	8		SANDY GRAVEL-SILTY SANDY GRAVEL: Brown, noncohesive, 5% cobbles to 4".
	SM			NP	96	24		SILTY SAND: Gray and yellow, fine grained, 5% cobbles to 5"
34.0'				NP	82	14		brown, gravel to 3"
37.0'	GP-GM			NP	46	6		SANDY GRAVEL-SILTY SANDY GRAVEL: Brown, 15% cobbles to 5".
40.0'	SW-SM			NP	80	8		SAND-SILTY SAND: Brown, coarse grained, gravel to 3", occasional cobble to 5", caving.
	SP-SM			NP	72	5		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, gravel to 3", caving
46.0'				NP	75	5		occasional cobble to 4" stopped drilling due to caving.

TH 80-17

EL. 544'	LOG	MC	LL	PI	-4	-200	N	
	SM			NP	88	26		SILTY SAND: Light-brown, noncohesive, gravel to 1"
				NP	96	27		gray and yellow, fine-grained sand, medium dense
6.5'				NP	91	28		light-brown, moderately cohesive.
8.0'	SC		34	18	91	44		CLAYEY SAND: Red-brown, stiff, cohesive.
11.0'	SM			NP	85	13		SILTY GRAVELLY SAND: Red-brown, medium dense, cohesive, gravel to 1", 1-6" cobble.
13.0'	SW-SM			NP	78	11		GRAVELLY SAND-SILTY GRAVELLY SAND: Red-brown, cohesive.
14.0'	CH		79	58	100	79		SANDY CLAY: Yellow-brown, cohesive.
	SW-SM			NP	62	7		GRAVELLY SAND-SILTY GRAVELLY SAND: Red-brown, 10% cobbles to 7", lenses of red, medium-grained sand.
19.0'				NP	88	11		SAND-SILTY SAND: Red-brown, occasional cobble to 4".
21.0'	SP-SM			NP	78	7		GRAVELLY SAND-SILTY GRAVELLY SAND: Light-brown, noncohesive, gravel to 3"
	SW-SM			NP	67	9		dark-brown, 20% cobbles to 6"
27.0'				NP	82	6		brown, lenses of red, medium-grained sand, 5% cobbles to 4"
30.0'	SP-SM			NP	73	8		occasional cobble to 6"
32.0'	ML		37	7	100	78		SANDY SILT: Gray and yellow, cohesive.
	SM			NP	87	38		SILTY SAND: Gray and yellow, cohesive.
				NP	67	24		SILTY GRAVELLY SAND: Brown and yellow, moderately cohesive, 10% cobbles to 4"
W 37.0'				NP	64	22		brown, cohesive, 5% cobbles to 4"
39.0'								
41.0'	SP-SM			NP	90	6		GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, cohesive, 5% cobbles to 4", 1-10" cobble
44.0'	SW-SM			NP	70	12		10% cobbles to 6", caving
46.0'	SP-SM			NP	76	7		stopped drilling due to caving.

TH 80-18

EL.574'	LOG	MC	LL	PI	-4	-200	N	
	ML		22	3	98	72		SANDY SILT: Brown, barely moist, moderately cohesive.
5.0'			20	3	99	77		
7.0'	CL		29	11	99	73		SANDY CLAY: Red-brown, barely moist, moderately cohesive, occasional gravel to 1".
9.0'	SM			NP	73	29		GRAVELLY SILTY SAND: Brown, moist, moderately cohesive, gravel to 2".
11.0'	SW-SM			NP	66	10		GRAVELLY SAND-SILTY GRAVELLY SAND: Red-brown, moist, noncohesive, gravel to 3"
12.5'	[illegible]			NP	55	9		brown, moderately cohesive
16.0'	SW-SM			NP	59	10		noncohesive, 10% cobbles to 6"
17.0'	SM			NP	82	19		GRAVELLY SILTY SAND: Red-brown, moist, moderately cohesive, gravel to 1"
18.0'	SC		33	13	89	40		CLAYEY SAND: Brown and grey, moist, moderately cohesive.
20.0'	CL		35	14	96	57		SANDY CLAY: Gray and yellow, moist, cohesive.
22.5'	GP-GM			NP	51	11		SANDY GRAVEL-SILTY SANDY GRAVEL: Brown, moist, noncohesive, 20% cobbles to 9"
	SM		34	7	91	[illegible]		SILTY SAND: Grey, barely moist, moderately cemented.
				NP	75	[illegible]		GRAVELLY SILTY SAND: Gray, barely moist.
				NP	75	[illegible]		SILTY GRAVELLY SAND: Gray and yellow, barely moist, moderately cohesive, gravel to 2".
				NP	100	[illegible]		SILTY SAND: Brown and yellow, barely moist, moderately cohesive
				NP	100	36		
				NP	99	41		layers of well-cemented sand to 1" thick.
				NP	100	[illegible]		
				NP	100	[illegible]		
				NP	100	[illegible]		
				NP	98	[illegible]		GRAVELLY SILTY SAND: Brown and yellow, barely moist, moderately cohesive.
81.0'				NP	99	[illegible]		SILTY SAND: Brown and yellow, barely moist, moderately cohesive.

Y VALUE ENGINEERING PAYS

t-brown, noncohesive,

fine-grained sand.

derately cohesive.

-brown, stiff, cohesive.
SAND: Red-brown, medium
, gravel to 1", 1-6"

ILTY GRAVELLY SAND:
sive.
low-brown, cohesive.
LTY GRAVELLY SAND:
cobbles to 7", lenses
grained sand.
: Red-brown, occasional

LTY GRAVELLY SAND:
ncohesive, gravel to 3"
cobbles to 6"

f red, medium-grained
e to 4"

le to 6"

y and yellow, cohesive.

and yellow, cohesive.
SAND: Brown and yellow,
sive, 10% cobbles to 4"
, 5% cobbles to 4"

LTY GRAVELLY SAND:
. 5% cobbles to 4",

", caving
due to caving.

own, barely moist, moderately

-brown, barely moist, moderately
sional gravel to 1".
SAND: Brown, moist, moderately
el to 2".
SILTY GRAVELLY SAND: Red-brown,
sive, gravel to 3"
ly cohesive
% cobbles to 6"

SAND: Red-brown, moist, moderately
el to 1"
rown and gray, moist, moderately

y and yellow, moist, cohesive.
ILTY SANDY GRAVEL: Brown, moist,
0% cobbles to 8"
y, barely moist, moderately

SAND: Gray, barely moist.
SAND: Gray and yellow, barely moist,
esive, gravel to 2".
own and yellow, barely moist,
esive

-cemented sand to 1" thick.

SAND: Brown and yellow, barely
ely cohesive.
own and yellow, barely moist,
esive.

NOTE:

1. See plate 17 for location of borings.
2. TH 80-15 to 18 were drilled in April 1980 with a 16-inch diameter bucket auger.
3. See plate 36 for legend.

VERTICAL SCALE: 1 INCH = 5 FEET

SCALE 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
TH 80-15 THRU TH 80-18

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-__-B-__

DISTRICT FILE NO.

SHEET

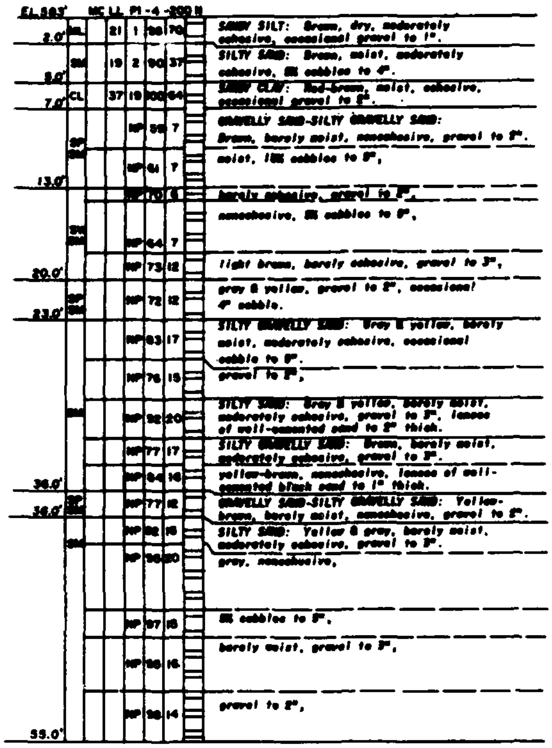
PLATE 5-42

SAFETY PAYS

1

2

TH 80-19



SANDY SILT: Brown, dry, moderately cohesive, occasional gravel to 1".

SILTY SAND: Brown, moist, moderately cohesive, 5% cobbles to 4".

SANDY CLAY: Red-brown, moist, cohesive, occasional gravel to 2".

GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, barely moist, noncohesive, gravel to 2".

moist, 10% cobbles to 5",

barely cohesive, gravel to 2",

noncohesive, 5% cobbles to 5",

light brown, barely cohesive, gravel to 3",

gray & yellow, gravel to 2", occasional 4" cobble.

SILTY GRAVELLY SAND: Gray & yellow, barely moist, moderately cohesive, occasional cobble to 5".

gravel to 2",

SILTY SAND: Gray & yellow, barely moist, moderately cohesive, gravel to 3", lenses of well-cemented sand to 2" thick.

SILTY GRAVELLY SAND: Brown, barely moist, moderately cohesive, gravel to 3".

yellow-brown, noncohesive, lenses of well-cemented black sand to 1" thick.

GRAVELLY SAND-SILTY GRAVELLY SAND: Yellow-brown, barely moist, noncohesive, gravel to 2".

SILTY SAND: Yellow & gray, barely moist, moderately cohesive, gravel to 3".

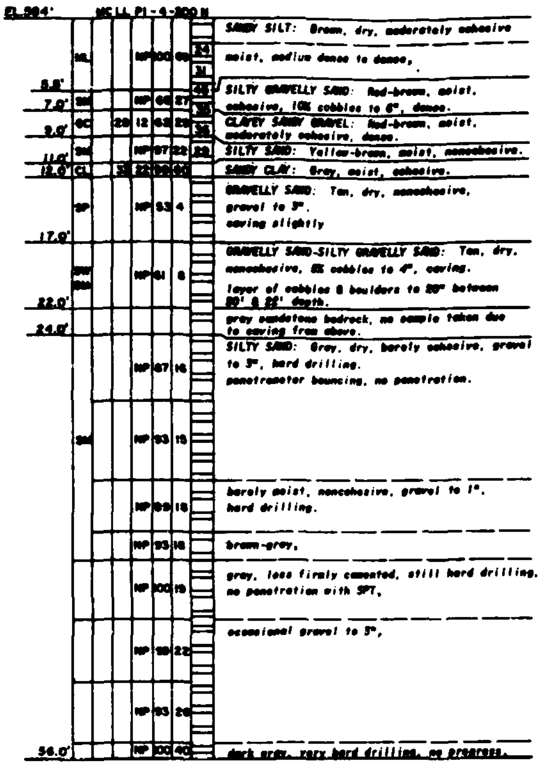
gray, noncohesive,

5% cobbles to 5",

barely moist, gravel to 3",

gravel to 2",

TH 80-20



SANDY SILT: Brown, dry, moderately cohesive

moist, medium dense to dense,

SILTY GRAVELLY SAND: Red-brown, moist, cohesive, 10% cobbles to 6", dense.

CLAYEY SANDY GRAVEL: Red-brown, moist, moderately cohesive, dense.

SILTY SAND: Yellow-brown, moist, noncohesive.

SANDY CLAY: Gray, moist, cohesive.

GRAVELLY SAND: Tan, dry, noncohesive, gravel to 3".
caving slightly

GRAVELLY SAND-SILTY GRAVELLY SAND: Tan, dry, noncohesive, 5% cobbles to 4", caving.
layer of cobbles & boulders to 20" between 20' & 22' depth.

gray sandstone bedrock, no sample taken due to caving from above.

SILTY SAND: Gray, dry, barely cohesive, gravel to 3", hard drilling.
penetrometer bouncing, no penetration.

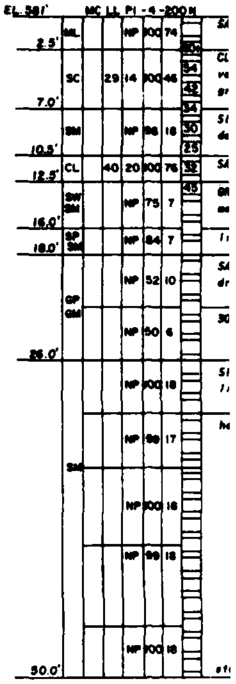
barely moist, noncohesive, gravel to 1", hard drilling.

brown-gray,

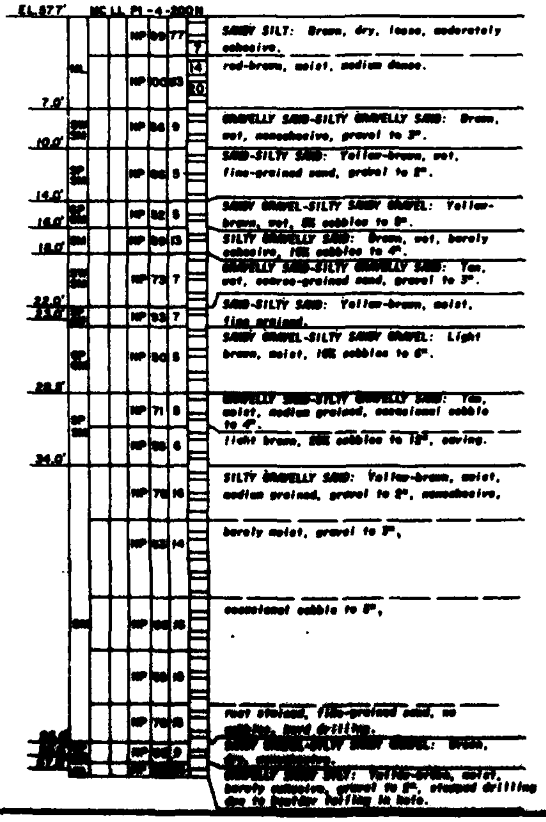
gray, less firmly cemented, still hard drilling, no penetration with SPT,

occasional gravel to 3",

dark gray, very hard drilling, no progress.



TH 80-22



SANDY SILT: Brown, dry, loose, moderately cohesive.

red-brown, moist, medium dense.

GRAVELLY SAND-SILTY GRAVELLY SAND: Brown, wet, noncohesive, gravel to 3".

SAND-SILTY SAND: Yellow-brown, wet, fine-grained sand, gravel to 2".

SANDY GRAVEL-SILTY SANDY GRAVEL: Yellow-brown, wet, 5% cobbles to 6".

SILTY GRAVELLY SAND: Brown, wet, barely cohesive, 10% cobbles to 4".

GRAVELLY SAND-SILTY GRAVELLY SAND: Tan, wet, coarse-grained sand, gravel to 3".

SAND-SILTY SAND: Yellow-brown, moist, fine grained.

SANDY GRAVEL-SILTY SANDY GRAVEL: Light brown, moist, 10% cobbles to 6".

GRAVELLY SAND-SILTY GRAVELLY SAND: Tan, moist, medium grained, occasional cobble to 4".

light brown, 20% cobbles to 12", caving.

SILTY GRAVELLY SAND: Yellow-brown, moist, medium grained, gravel to 2", noncohesive,

barely moist, gravel to 3",

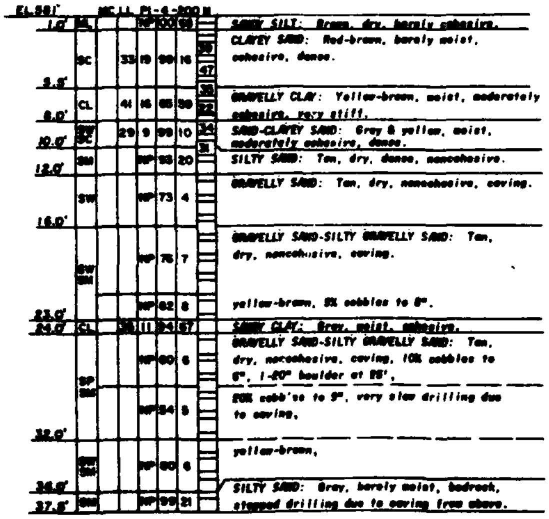
occasional cobble to 5",

rust stained, fine-grained sand, no cobbles, hard drilling.

SANDY GRAVEL-SILTY SANDY GRAVEL: Brown, dry, noncohesive.

GRAVELLY SANDY SILT: Yellow-brown, moist, barely cohesive, gravel to 2", stopped drilling due to boulder falling in hole.

TH 80-23



SANDY SILT: Brown, dry, barely cohesive.

CLAYEY SAND: Red-brown, barely moist, cohesive, dense.

GRAVELLY CLAY: Yellow-brown, moist, moderately cohesive, very stiff.

SAND-CLAYEY SAND: Gray & yellow, moist, moderately cohesive, dense.

SILTY SAND: Tan, dry, dense, noncohesive.

GRAVELLY SAND: Tan, dry, noncohesive, caving.

GRAVELLY SAND-SILTY GRAVELLY SAND: Tan, dry, noncohesive, caving.

yellow-brown, 5% cobbles to 6".

SANDY CLAY: Gray, moist, cohesive.

GRAVELLY SAND-SILTY GRAVELLY SAND: Tan, dry, noncohesive, caving, 10% cobbles to 6", 1-20" boulder at 28',

20% cobbles to 9", very slow drilling due to caving,

yellow-brown,

SILTY SAND: Gray, barely moist, bedrock, stopped drilling due to caving from above.

, moderately cohesive
dense,
ed-brown, moist,
o 6", dense.
ed-brown, moist,
nse.
wn, moist, noncohesive.
, cohesive.
y, noncohesive.
VELLY SAND: Tan, dry,
to 4", caving.
ders to 20" between
no sample taken due
barely cohesive, gravel
no penetration.
ve, gravel to 1",
red, still hard drilling.
illing, no progress.
ry, barely cohesive.
wn, barely moist,
-brown, moist, moderately
y & yellow, moist,
dense.
dense, noncohesive.
dry, noncohesive, caving.
AVELLY SAND: Tan,
ng.
les to 8".
ist, cohesive.
RAVELLY SAND: Tan,
ing, 10% cobbles to
25'.
y slow drilling due
ely moist, bedrock,
o caving from above.

TH 80-21

EL 381'

Depth		MC	LL	PI	-4	-200	
2.5'	ML			NP	100	74	SANDY SILTY: Brown, dry, moderately cohesive.
7.0'	SC		29	14	100	46	CLAYEY SAND: Red-brown, barely moist, dense to very dense, moderately cohesive, occasional gravel to 2".
10.5'	SM			NP	[illegible]	[illegible]	SILTY SAND: Yellow-brown, moist, medium dense to dense, barely cohesive, gravel to 1".
12.5'	CL		40	20	100	76	SANDY CLAY: Gray, moist, hard, cohesive.
16.0'	SW-SM			NP	75	7	GRAVELLY SAND-SILTY GRAVELLY SAND: Tan, barely moist, dense, noncohesive, gravel to 2", caving.
18.0'	SP-SM			NP	64	7	light tan, dry, 10% cobbles to 8",
	GP-GM			NP	52	10	SANDY GRAVEL-SILTY SANDY GRAVEL: Yellow-brown, dry, noncohesive, 10% cobbles to 7", caving.
28.0'				NP	80	6	30% cobbles to 14".
	SM			NP	100	16	SILTY SAND: Gray, barely moist, bedrock, very little cohesion in disturbed samples.
				NP	99	17	hard drilling, no penetration with SPT,
				NP	100	16	
				NP	99	16	
50.0'				NP	100	16	stopped drilling, boulder fell in hole.

NOTE:

1. SEE PLATE 19 FOR LOCATION OF BORINGS.
2. TH80-19 TO 23 WERE DRILLED IN APRIL 1980 WITH A 16 INCH DIAMETER BUCKET AUGER.
3. SEE PLATE 36 FOR LEGEND.

VERTICAL SCALE

SCALE 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS
TH 80-19 THRU TH 80-23

SPEC. NO. DACW09-___ B-___

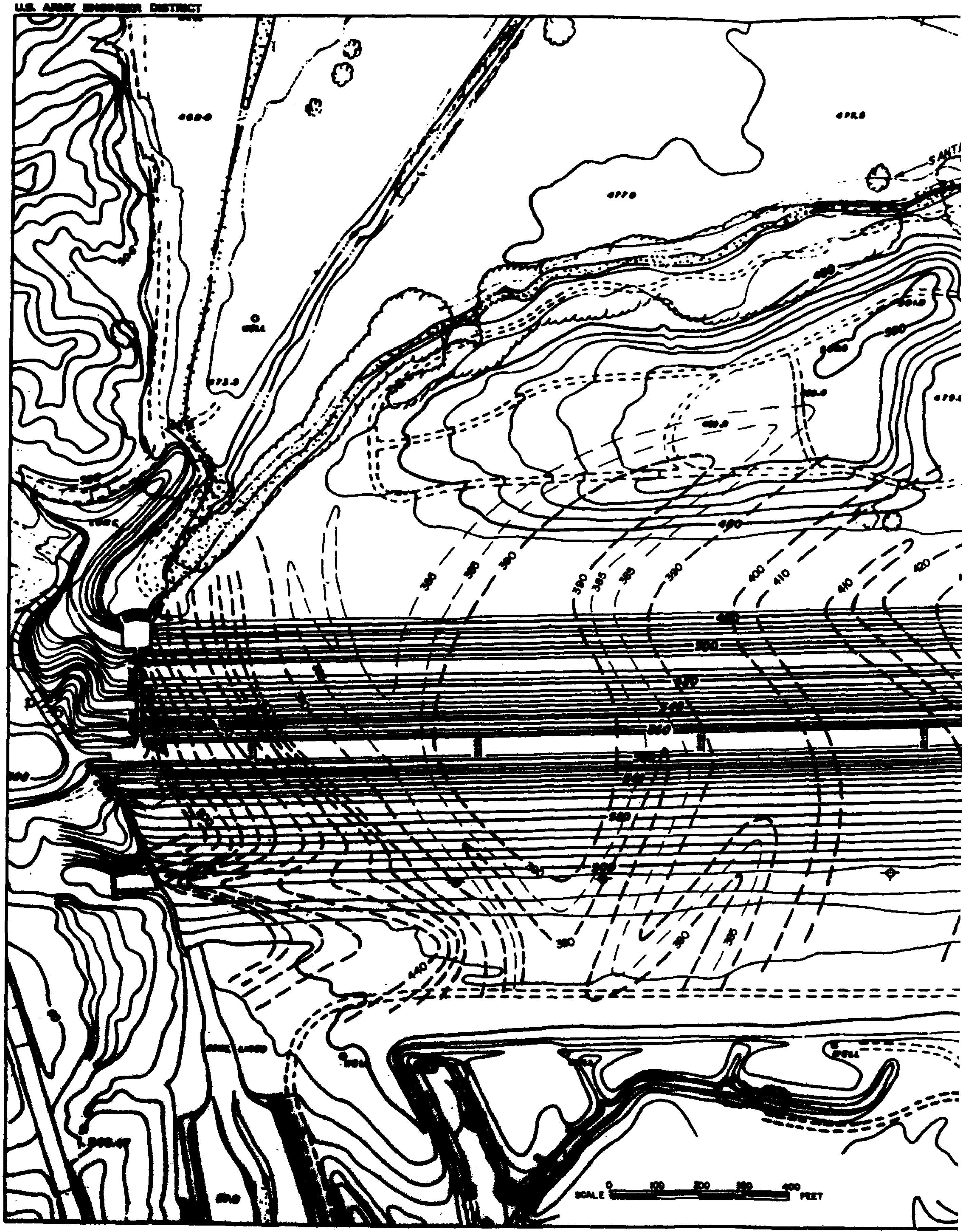
DISTRICT FILE NO.

PLATE B-46

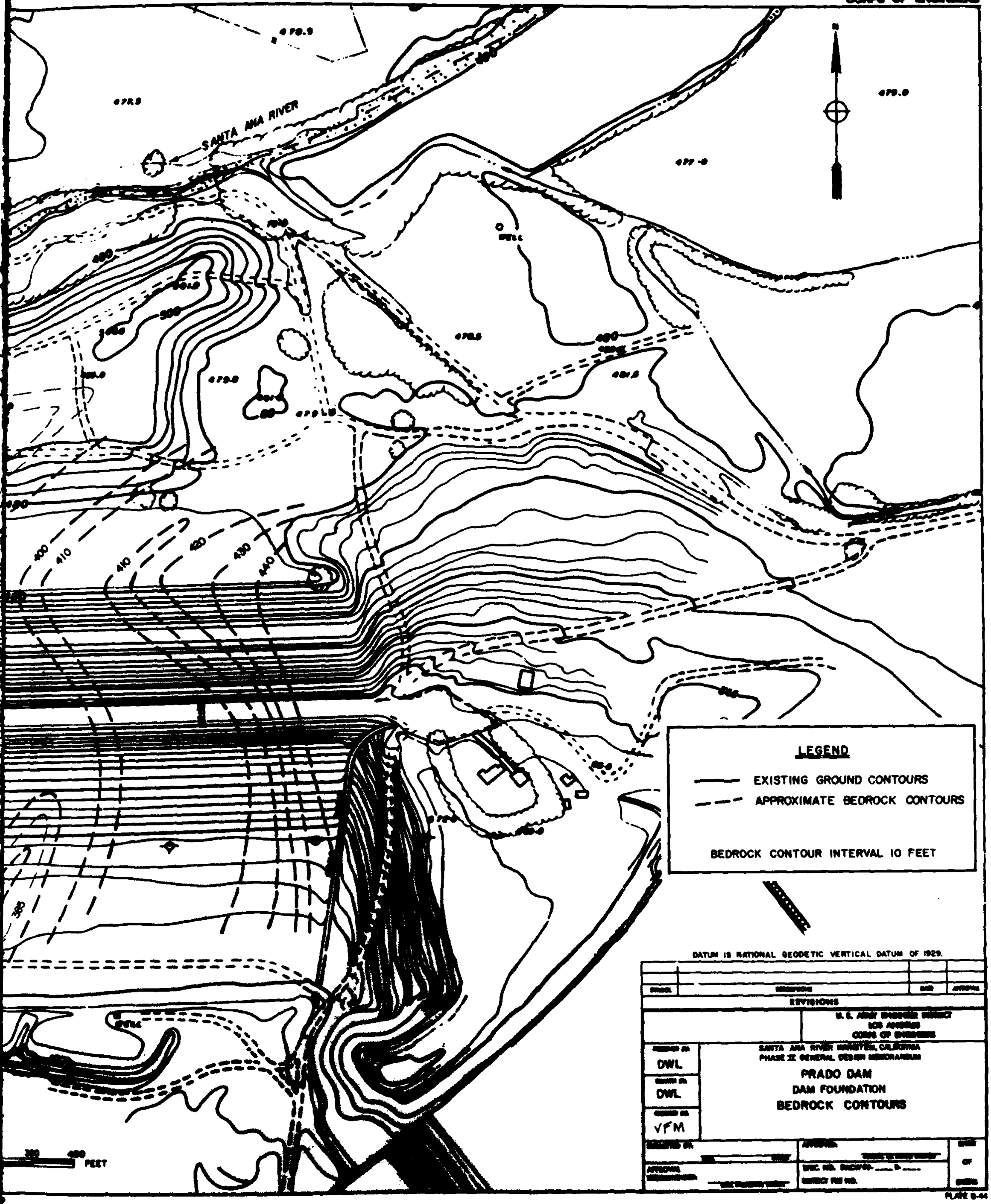
2

1

U.S. ARMY ENGINEER DISTRICT



CORPS OF ENGINEERS



LEGEND

- EXISTING GROUND CONTOURS
- APPROXIMATE BEDROCK CONTOURS

BEDROCK CONTOUR INTERVAL 10 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DWL
DWL
VFM

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

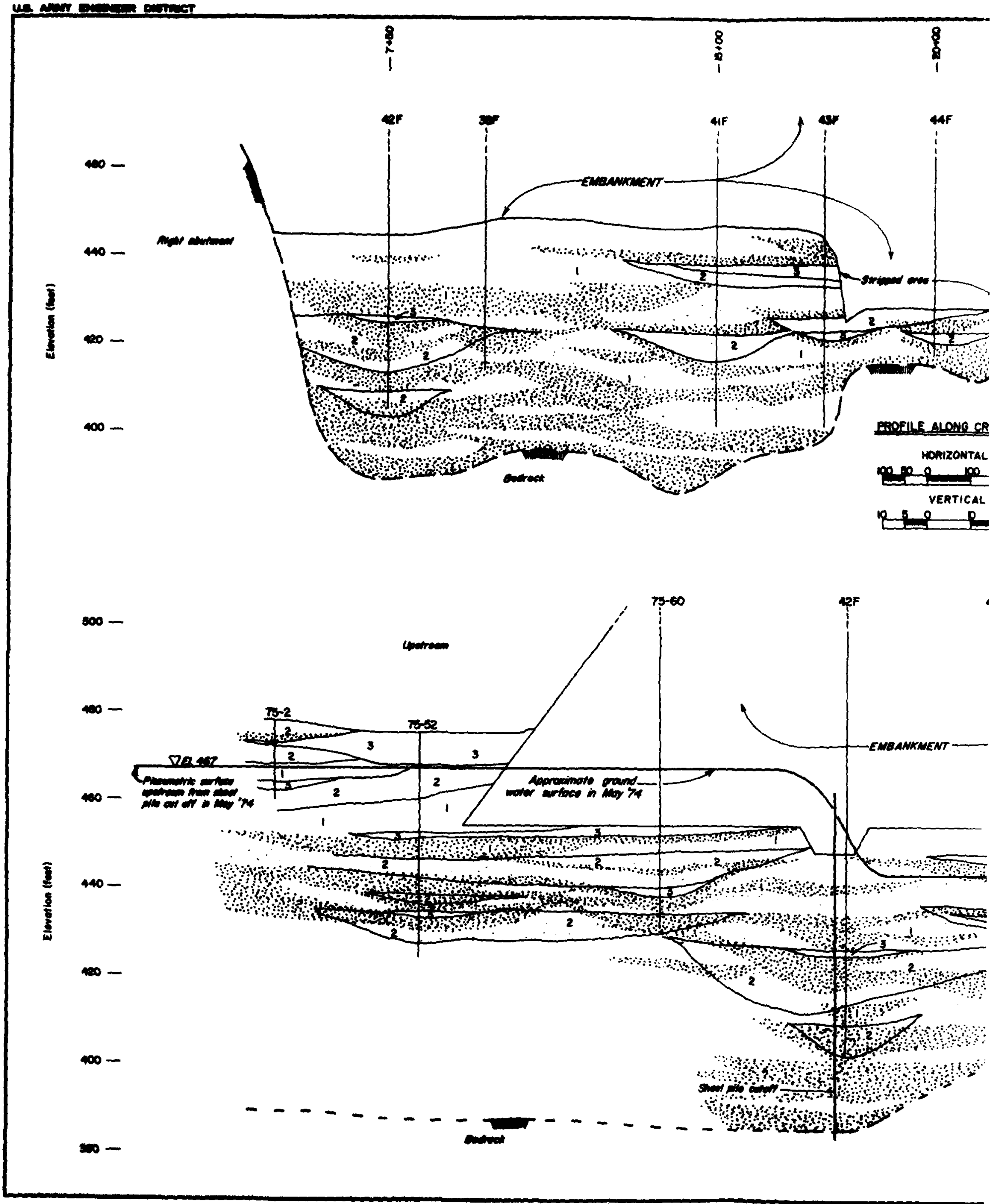
PRADO DAM
DAM FOUNDATION
BEDROCK CONTOURS

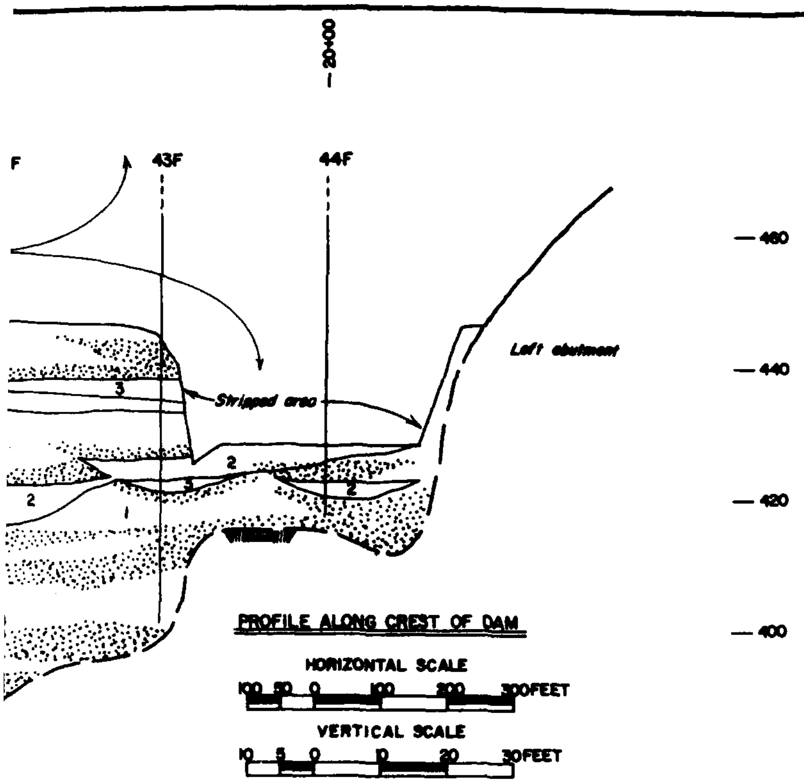
PLATE B-44

2

1

U.S. ARMY ENGINEER DISTRICT





PROFILE ALONG CREST OF DAM

HORIZONTAL SCALE
100 50 0 100 200 300FEET

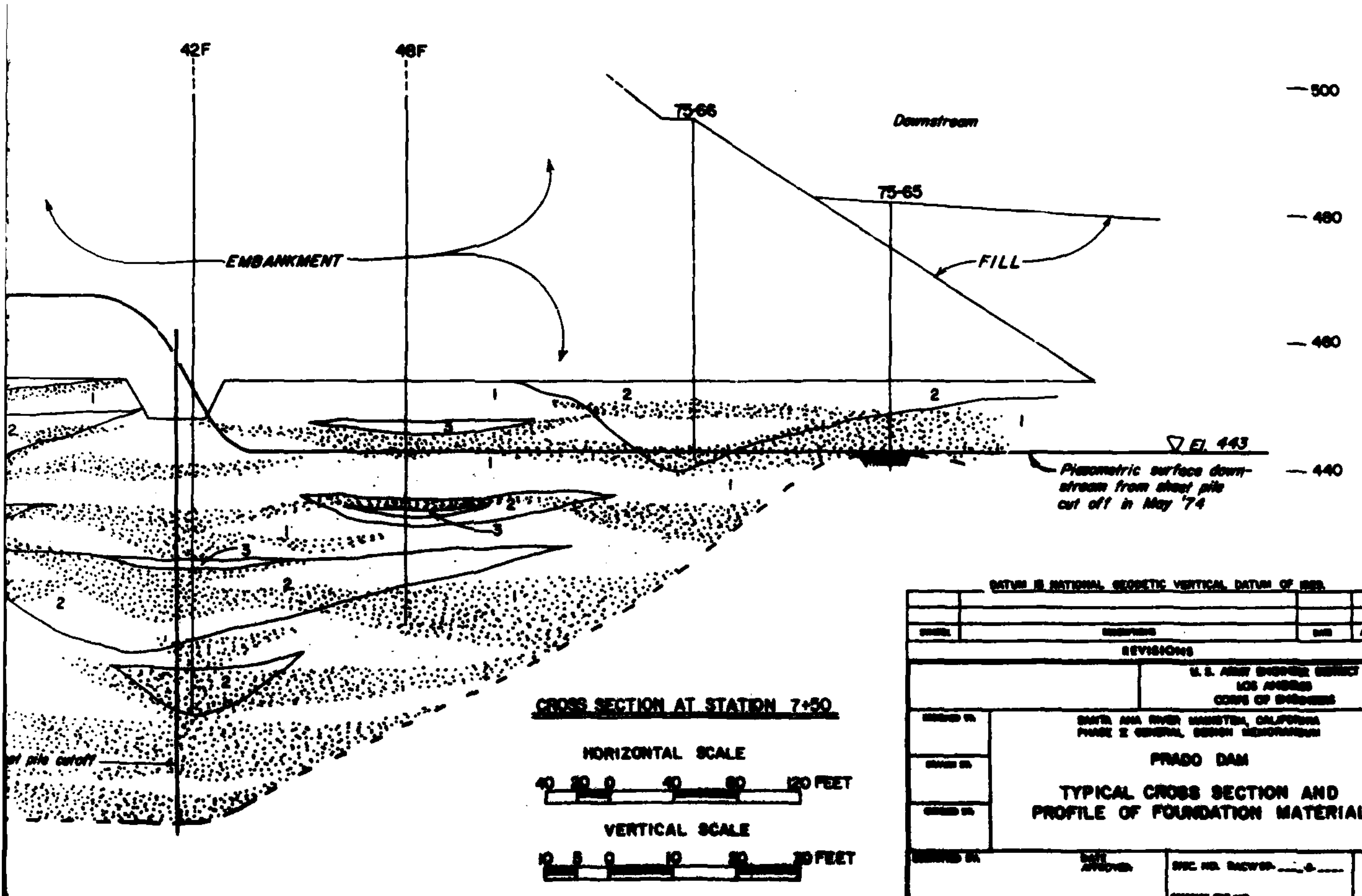
VERTICAL SCALE
10 5 0 10 20 30FEET

LEGEND

1	Sands and borderline sands
2	Silty sands and clayey sands
3	Silts and clays
⁙	Gravelly zone, more than 15% gravel
43F	Test hole drilled with Failing rig
75-60	Test hole drilled with bucket auger
——	Bedrock contact
— —	Approximate bedrock contact
- -	Inferred bedrock contact

NOTES

1. SEE PLATE 10 FOR LOCATIONS OF BORINGS
2. SEE PLATES 23, 28, 32, 33 and 35 FOR LOGS OF BORINGS



CROSS SECTION AT STATION 7+50

HORIZONTAL SCALE
40 20 0 40 80 120 FEET

VERTICAL SCALE
10 5 0 10 20 30 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE I GENERAL DESIGN MEMORANDUM

PRADO DAM

TYPICAL CROSS SECTION AND
PROFILE OF FOUNDATION MATERIALS

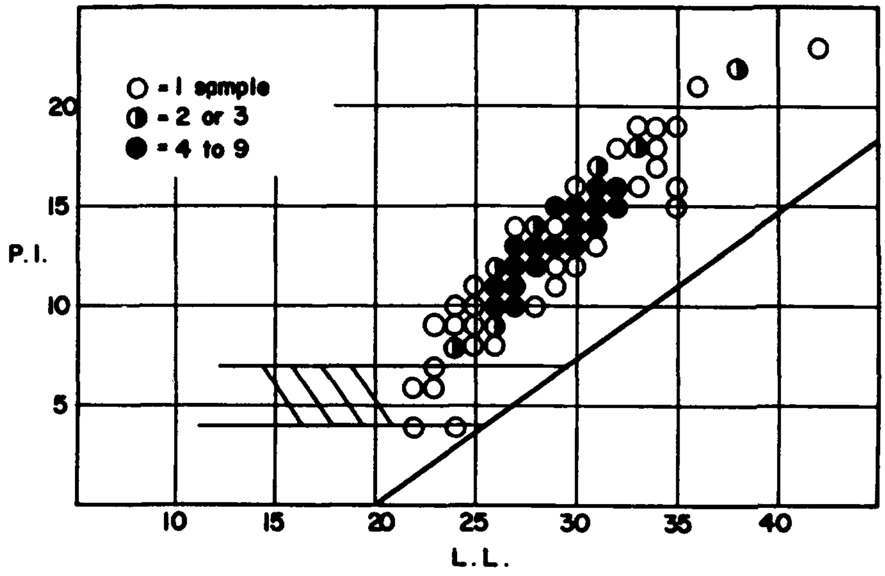
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___-___
DRAWING FILE NO.
SHEET

PLATE B-46

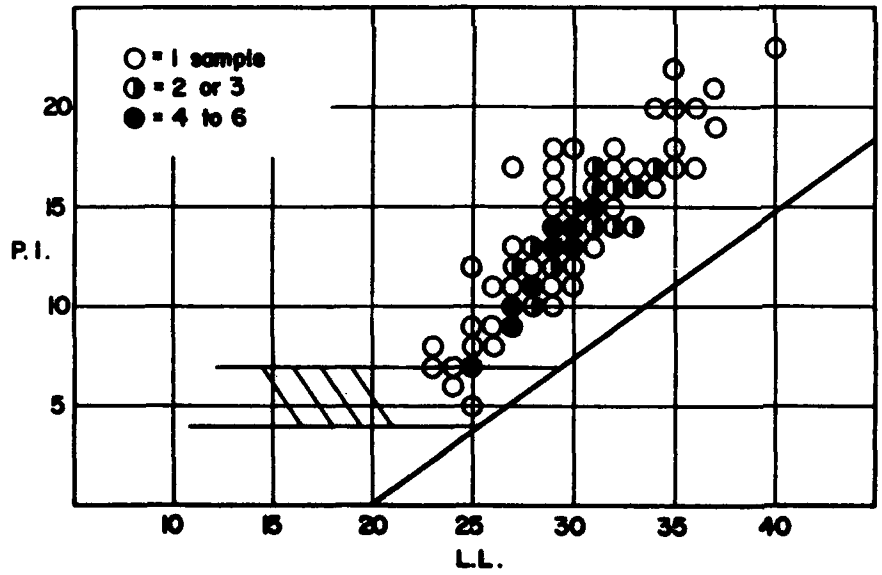
1

2

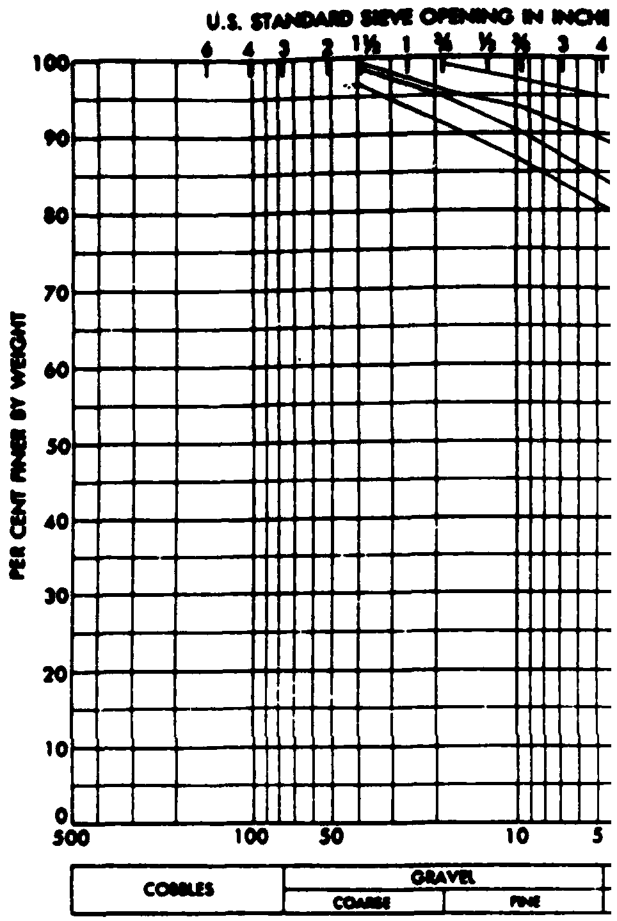
PLASTICITY CHART FOR RANDOM MATERIAL



PLASTICITY CHART FOR CORE MATERIAL

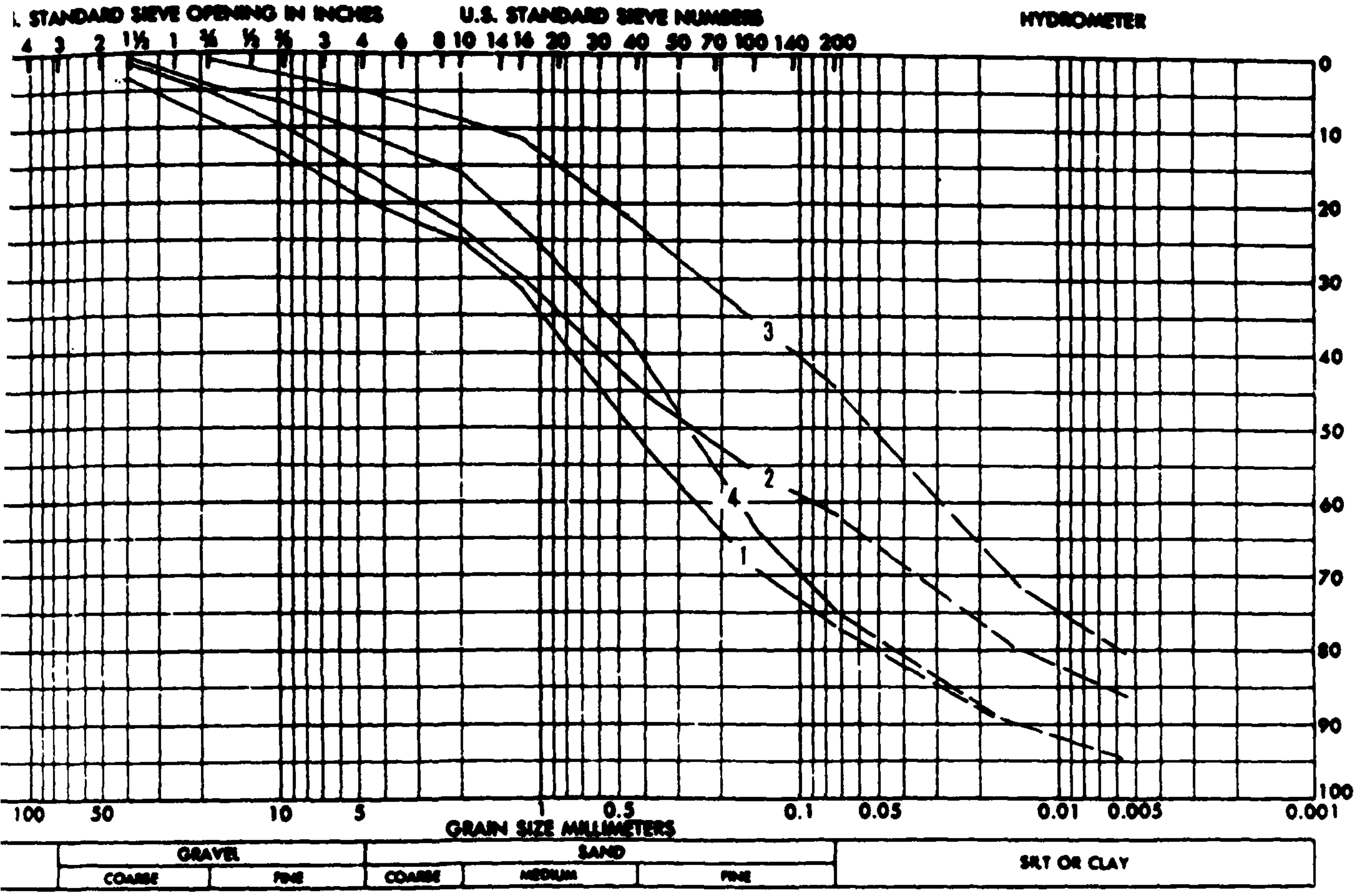


AVERAGE GRADATIONS



ZONE		CLASSIFICATION
1	U. S. PERVIOUS	SM, SILTY SAND
2	RANDOM	SC, CLAYEY SAND
3	CORE	CL, SANDY CLAY
4	D. S. PERVIOUS	SM, SILTY SAND

AGE GRADATIONS FOR EMBANKMENT MATERIALS, JAN. 1974



	CLASSIFICATION
US	SM, SILTY SAND
	SC, CLAYEY SAND
	CL, SANDY CLAY
US	SM, SILTY SAND

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

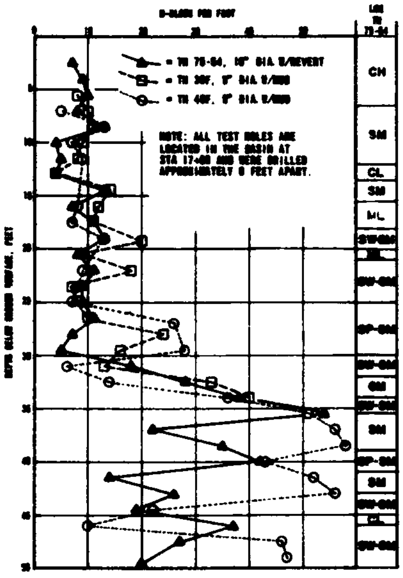
PRADO DAM

DAM EMBANKMENT MATERIALS
AVERAGE GRADATIONS AND PLASTICITY CHARTS

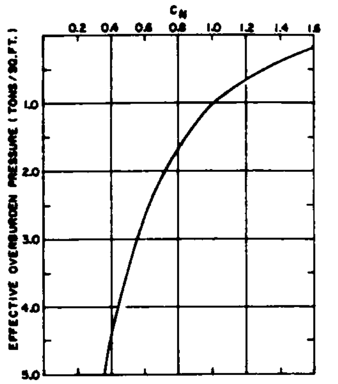
SUBMITTED BY
DATE APPROVED
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-46

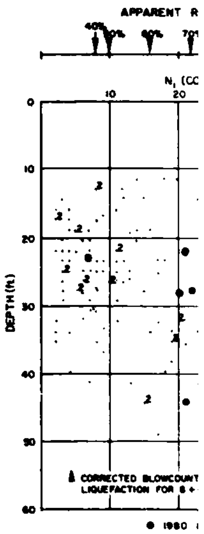
2



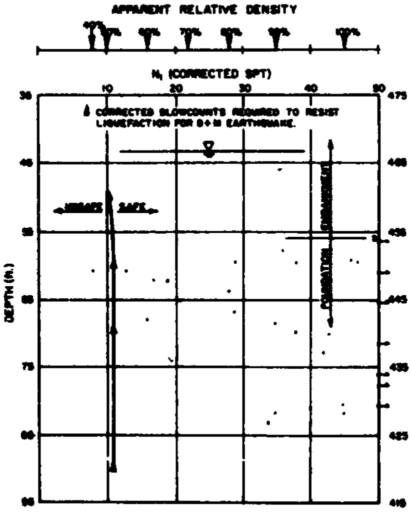
STANDARD PENETRATION TEST COMPARISON
WITH 5-INCH AND 16-INCH TEST HOLES



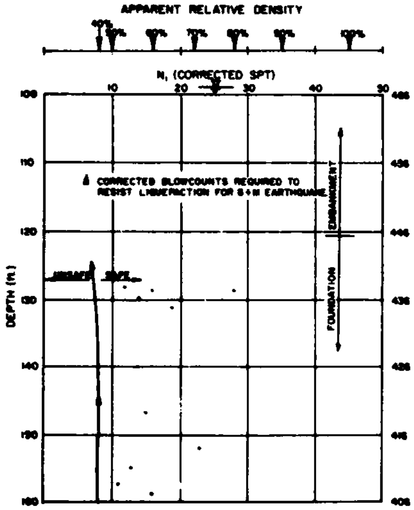
RECOMMENDED CURVES FOR DETERMINATION OF C_N
BASED ON AVERAGES FOR W.E.S. TESTS



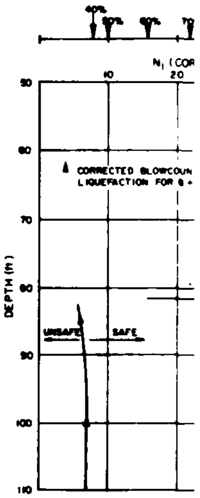
SECT
CORRECTED ST
TEST RE
FOR SAND



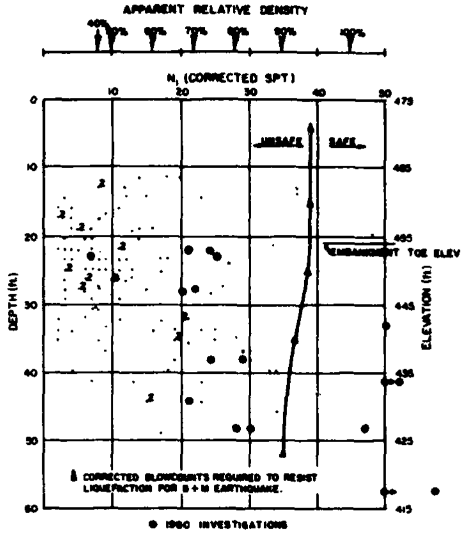
SECTION C, α = 0.12
CORRECTED STANDARD PENETRATION
TEST RESULTS VS. DEPTH
FOR SANDS W/+#4 ≤12% ≥ -#200



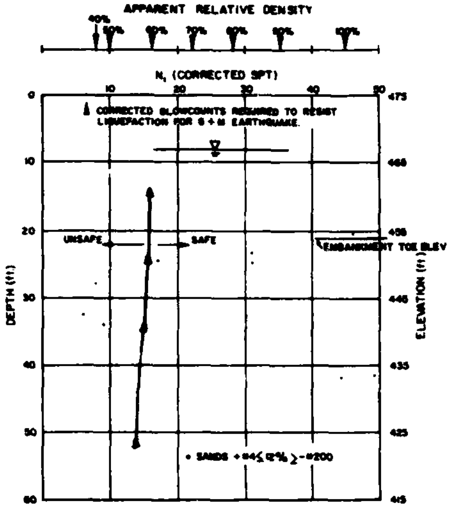
SECTION D, α = 0.08
CORRECTED STANDARD PENETRATION
TEST RESULTS VS. DEPTH
FOR SANDS W/+#4 ≤12% ≥ -#200



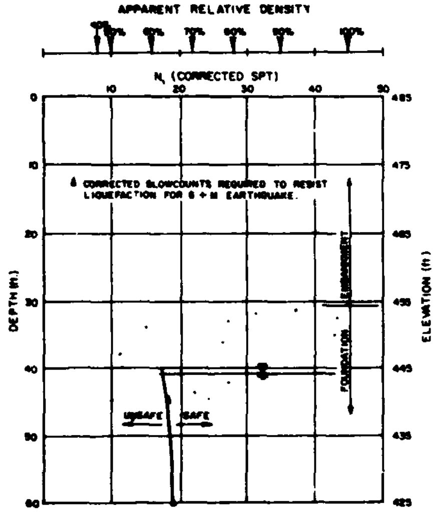
SECTIO
CORRECTED STA
TEST RES
FOR SANDS W/



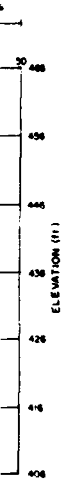
SECTION A, α = 0.0
CORRECTED STANDARD PENETRATION
TEST RESULTS VS. DEPTH
FOR SANDS W/+#4 ≤ 12% ≥ -#200

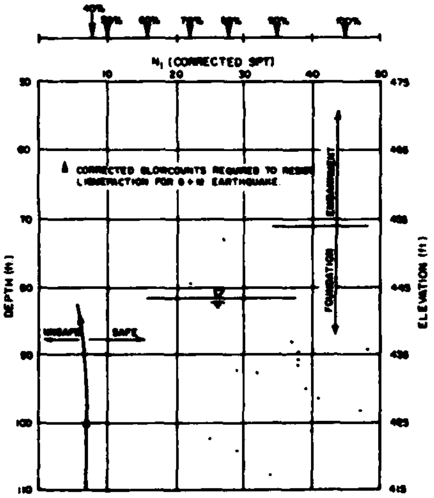


SECTION B, α = 0.15
CORRECTED STANDARD PENETRATION
TEST RESULTS VS. DEPTH
FOR SANDS W/+#4 ≤ 12% ≥ 200



SECTION C, α = 0.045
CORRECTED STANDARD PENETRATION
TEST RESULTS VS. DEPTH
FOR SANDS W/+#4 ≤ 12% ≥ -#200





SECTION E, α = 0.08
CORRECTED STANDARD PENETRATION
TEST RESULTS VS. DEPTH
FOR SANDS W/+#4 ≤ 12% ≥ -#200

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

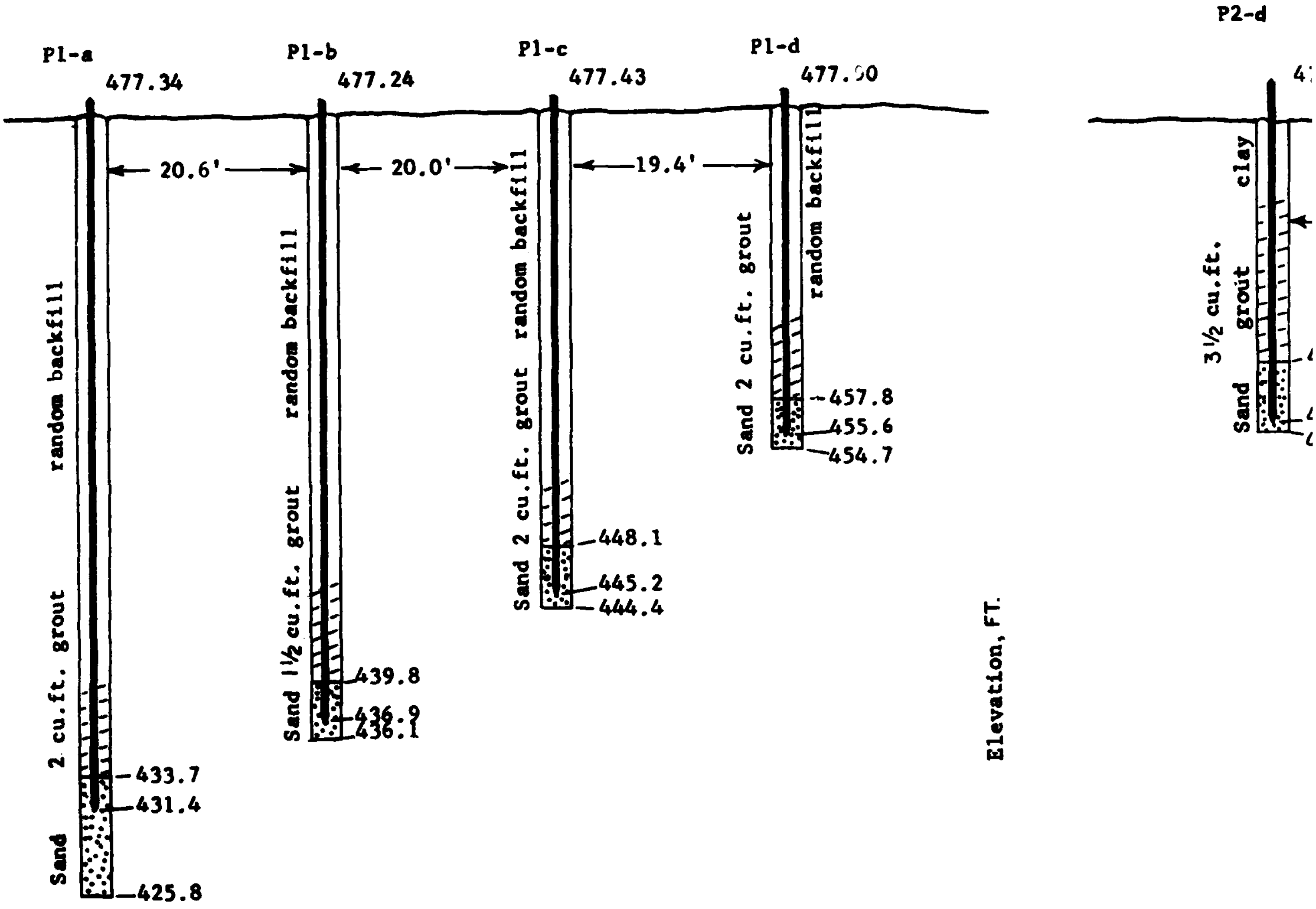
PRADO DAM

CORRECTED STANDARD PENETRATION TEST
RESULTS VS. DEPTH

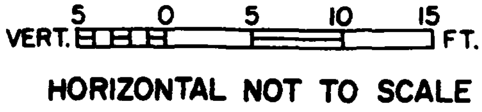
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____-B-____
SUBJECT FILE NO.
SHEET

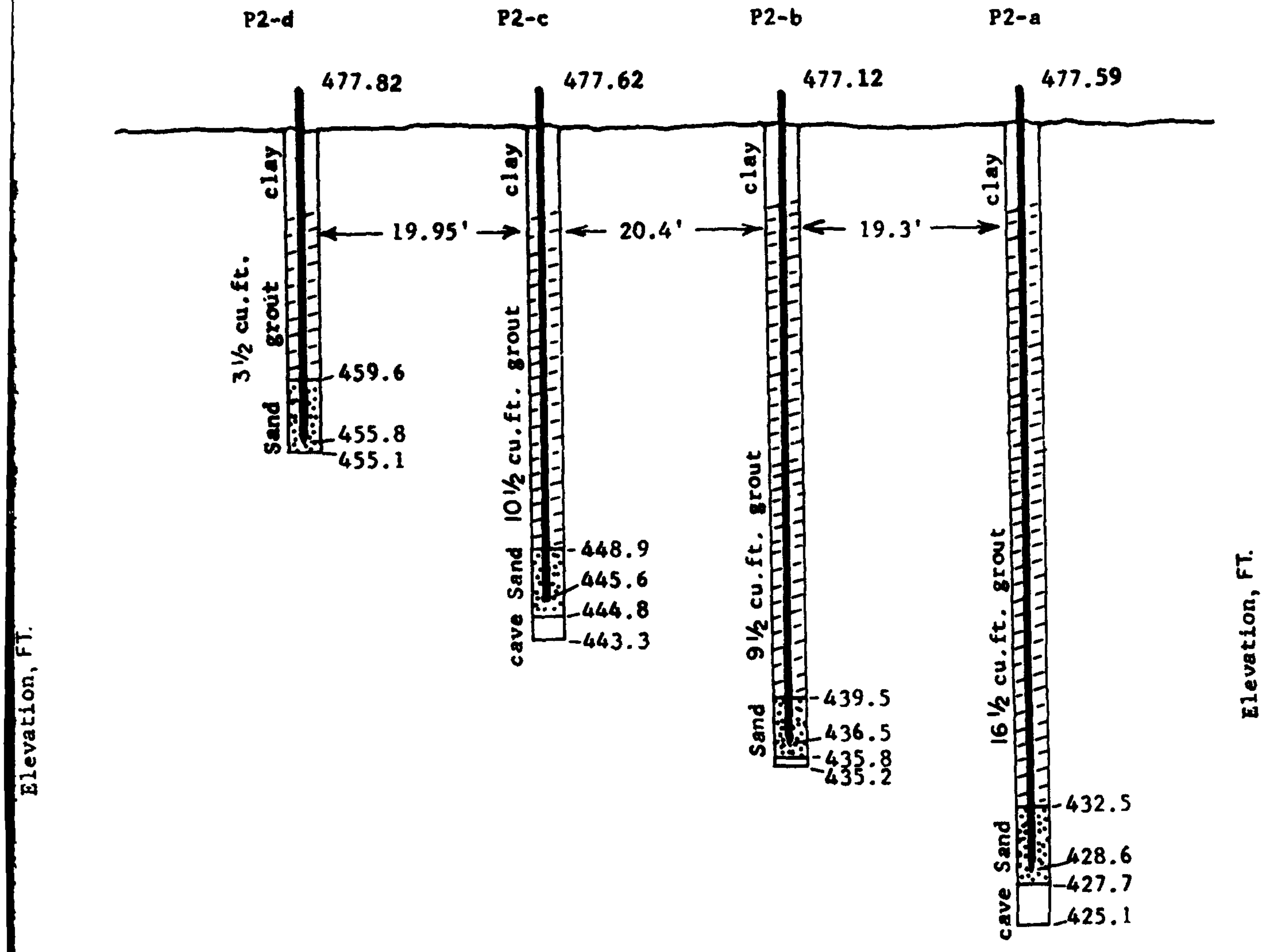
PLATE B-47

2



CROSS SECTION OF PIEZOMETER SET I





CROSS SECTION OF PIEZOMETER SET 2

0 5 10 15 FT.

NTAL NOT TO SCALE

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

PIEZOMETERS: LOCATIONS,
CROSS SECTIONS AND GROUNDWATER DATA

DATE APPROVED

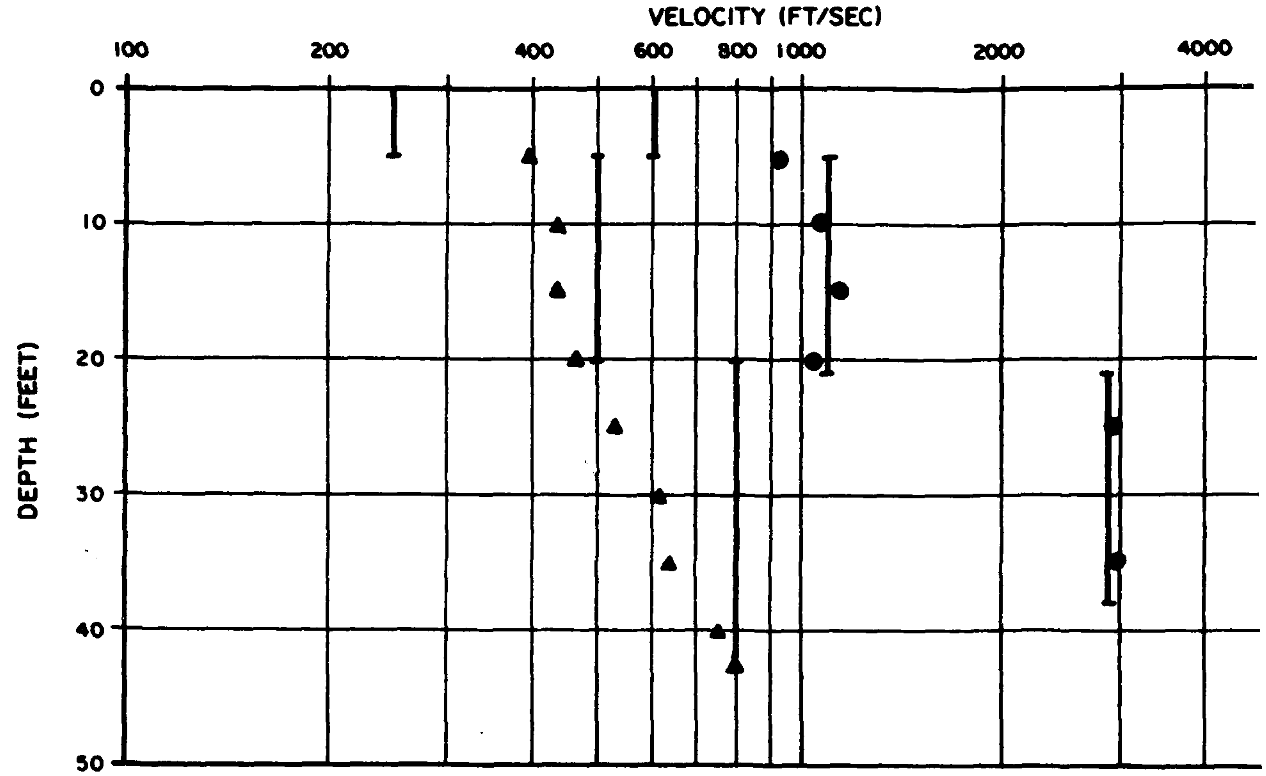
SPEC. NO. DACW09-___ B-___

DISTRICT FILE NO.

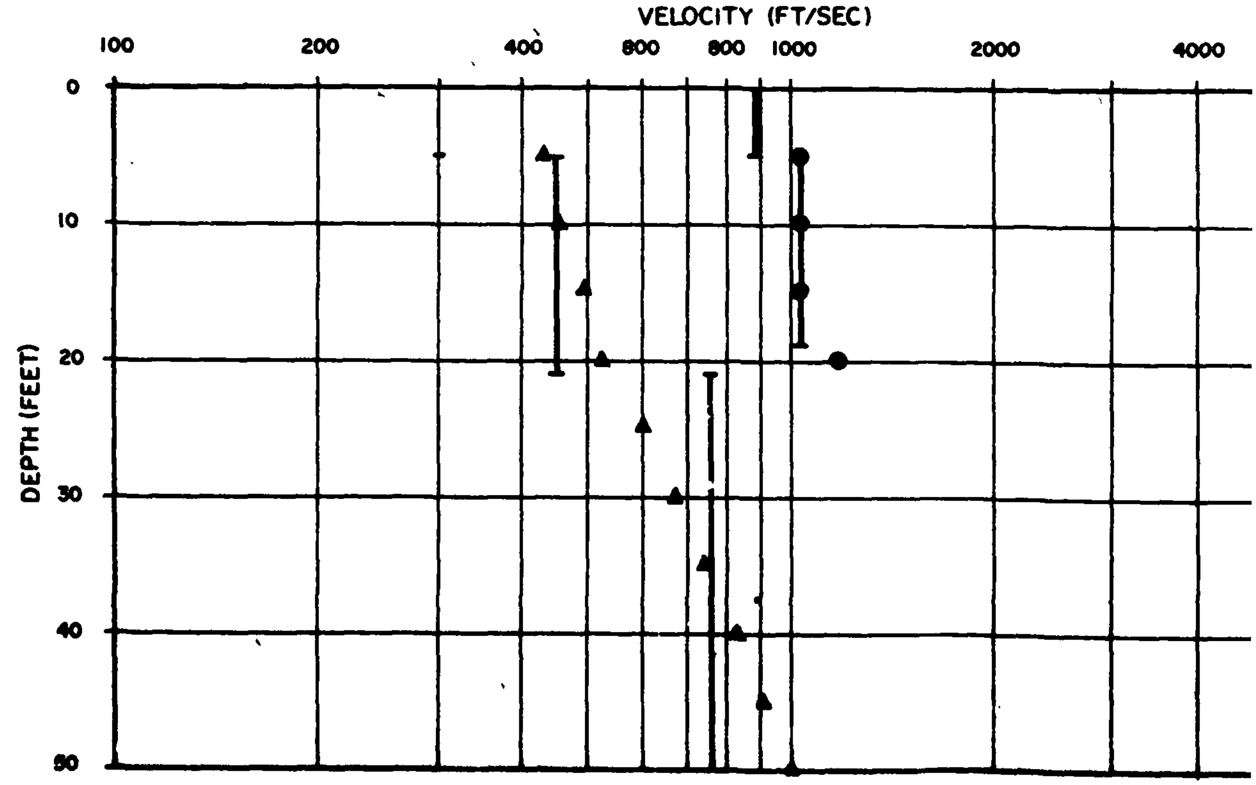
1

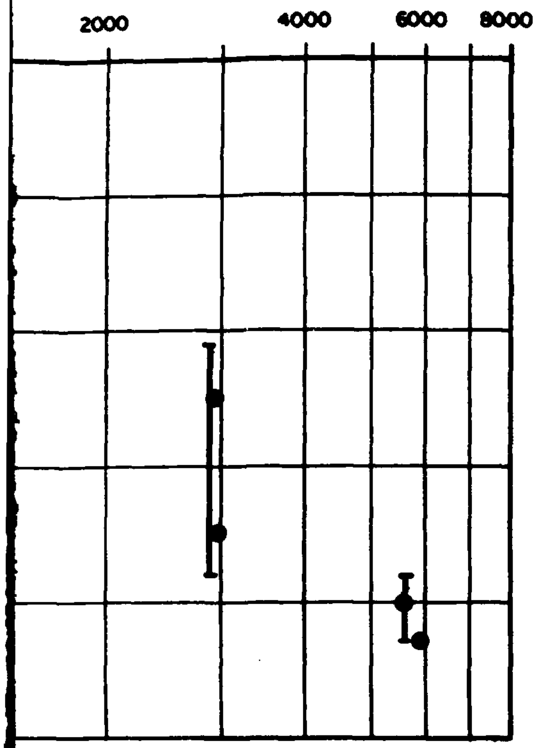
2

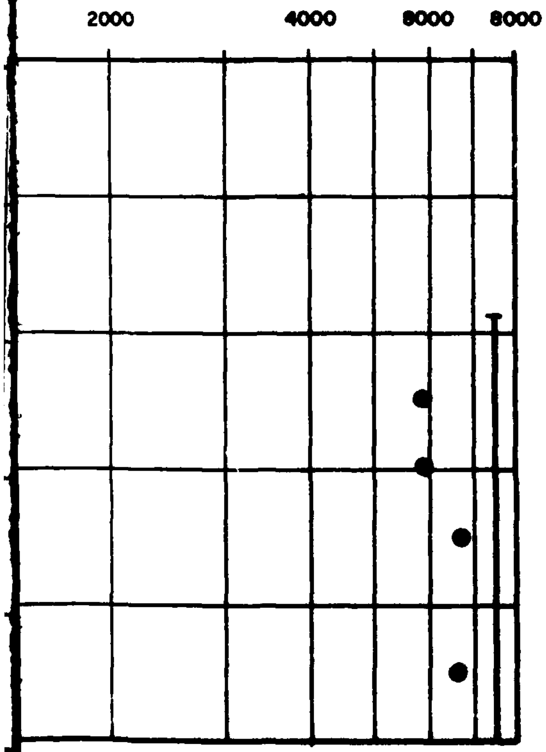
HOLE NO. 53F, 52F, 51F
STA. 6+80



HOLE NO. 54F, 50F, 49F
STA. 15+00







LEGEND

● COMPRESSIONAL WAVE VELOCITY

▲ SHEAR WAVE VELOCITY

I VELOCITIES FROM DOWNHOLE SURVEY

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
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SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

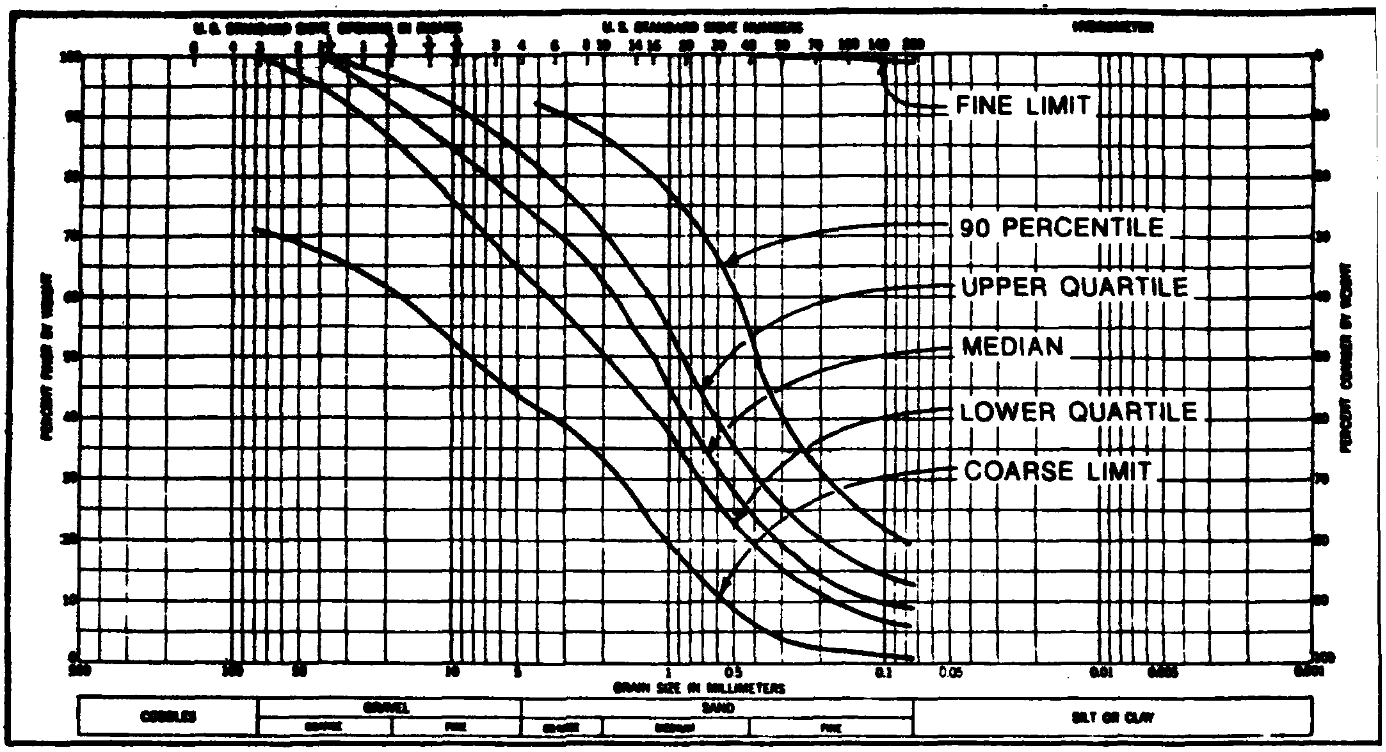
DAM FOUNDATION MATERIALS
SEISMIC VELOCITY PROFILES

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

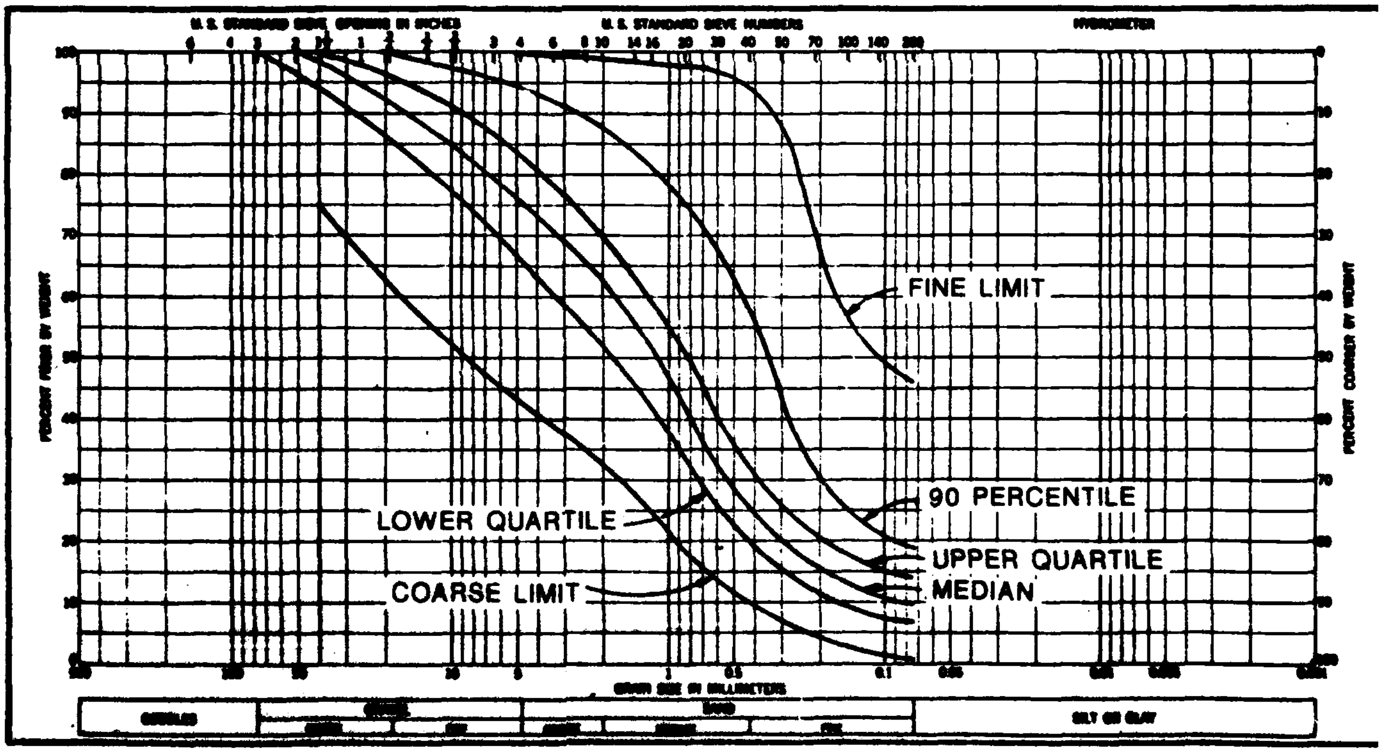
PLATE B-49

1

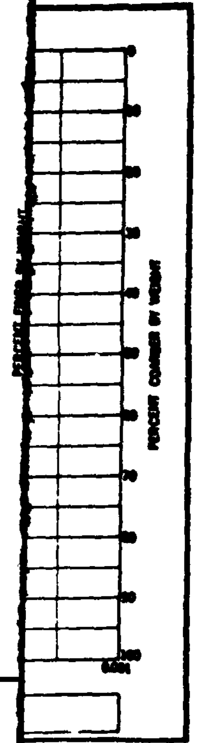
9

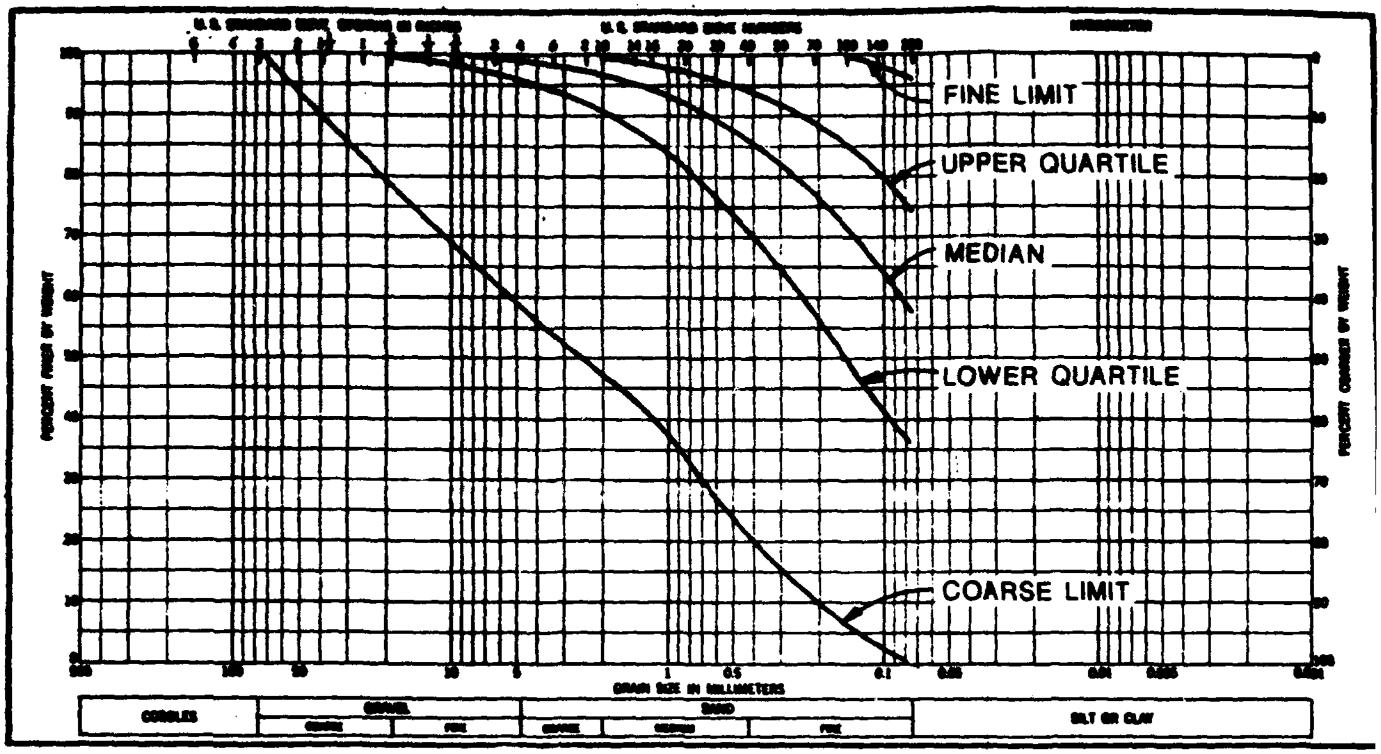


ZONE I BORROW
UNBLENDED

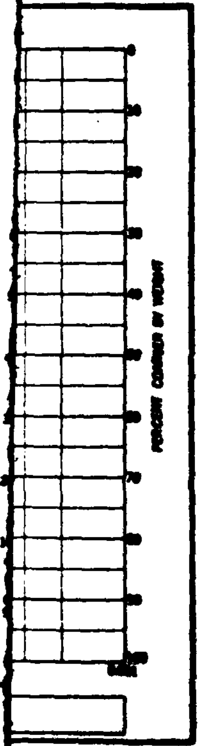


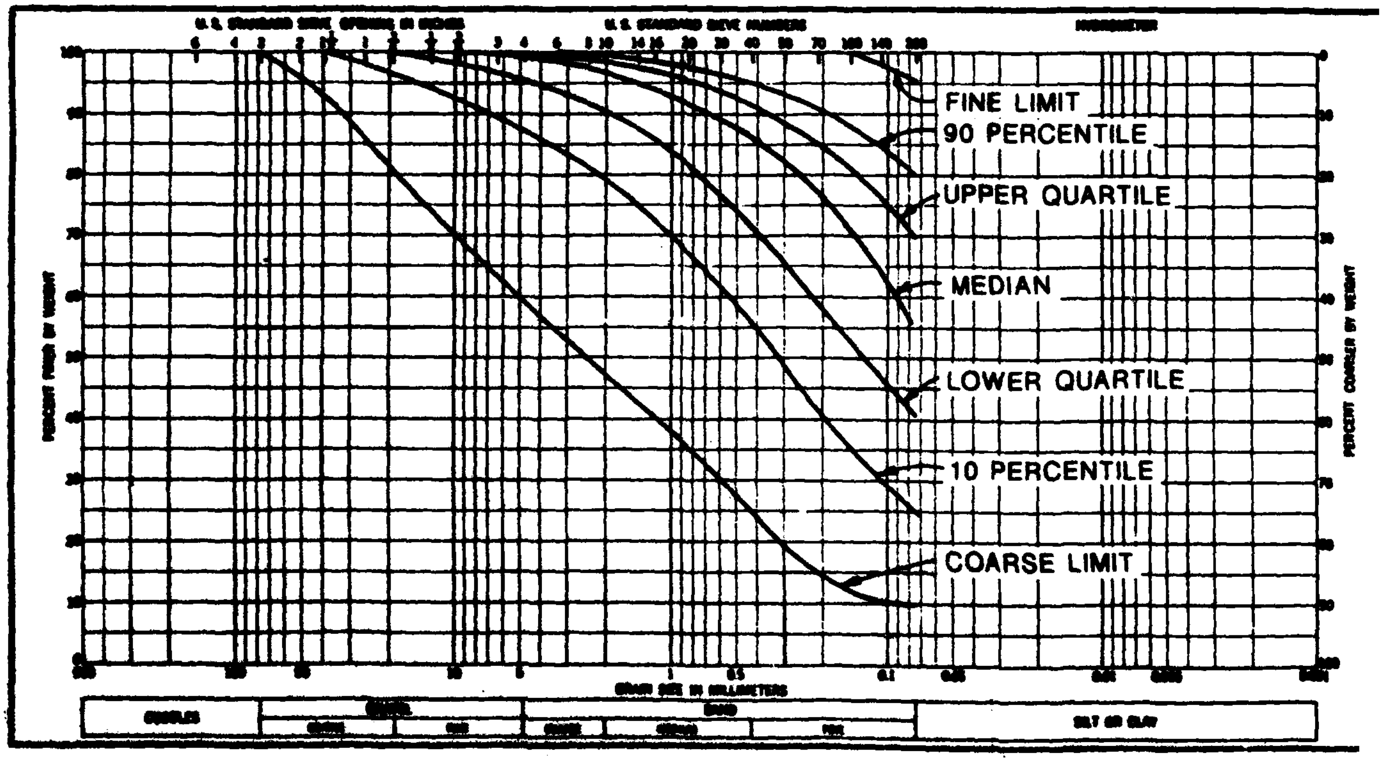
ZONE I BORROW
EXCAV. 5 AVE. DEPTH





ZONE II BORROW
UNBLENDED

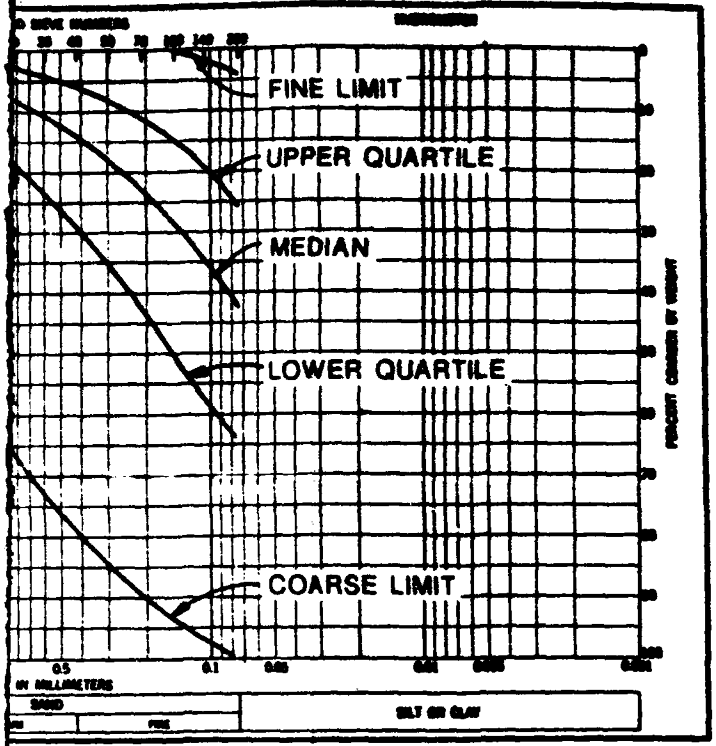




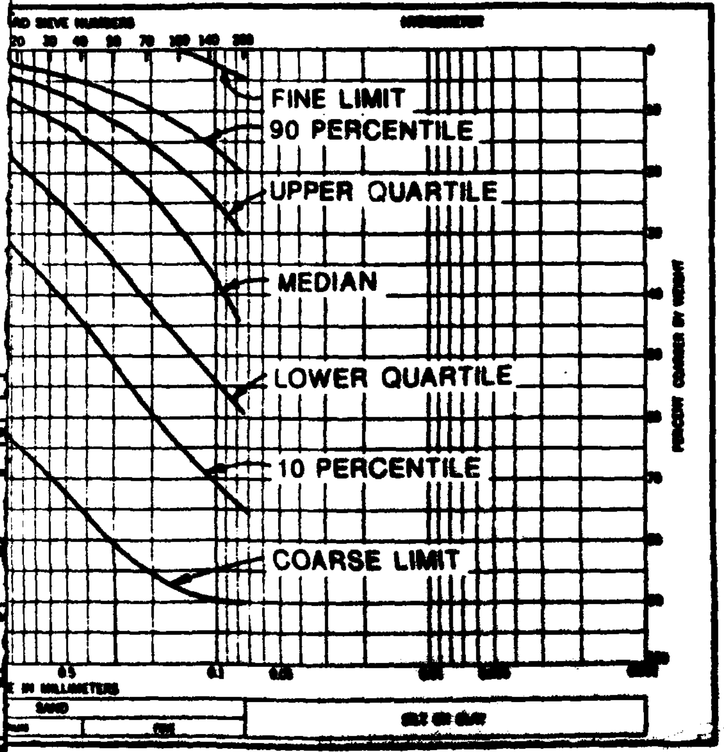
ZONE II BORROW
EXCAV. 5' AVE. DEPTH

1

2



BORROW
ENDED



I BORROW
AVE. DEPTH

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

BORROW MATERIALS
ZONE I AND ZONE II GRADATION LIMITS

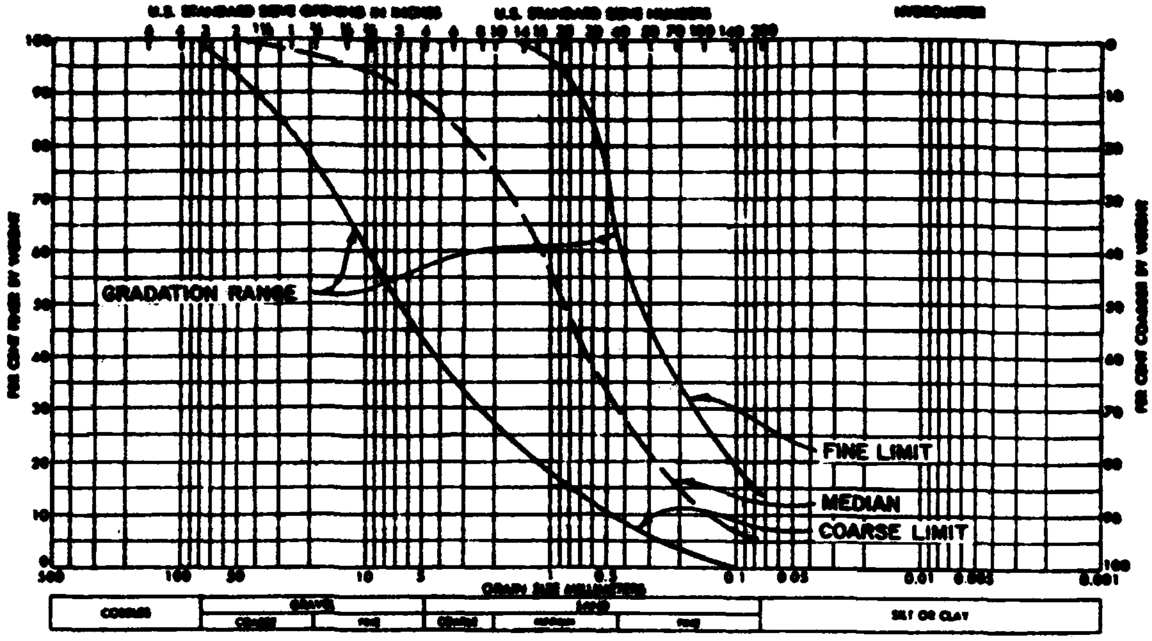
SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

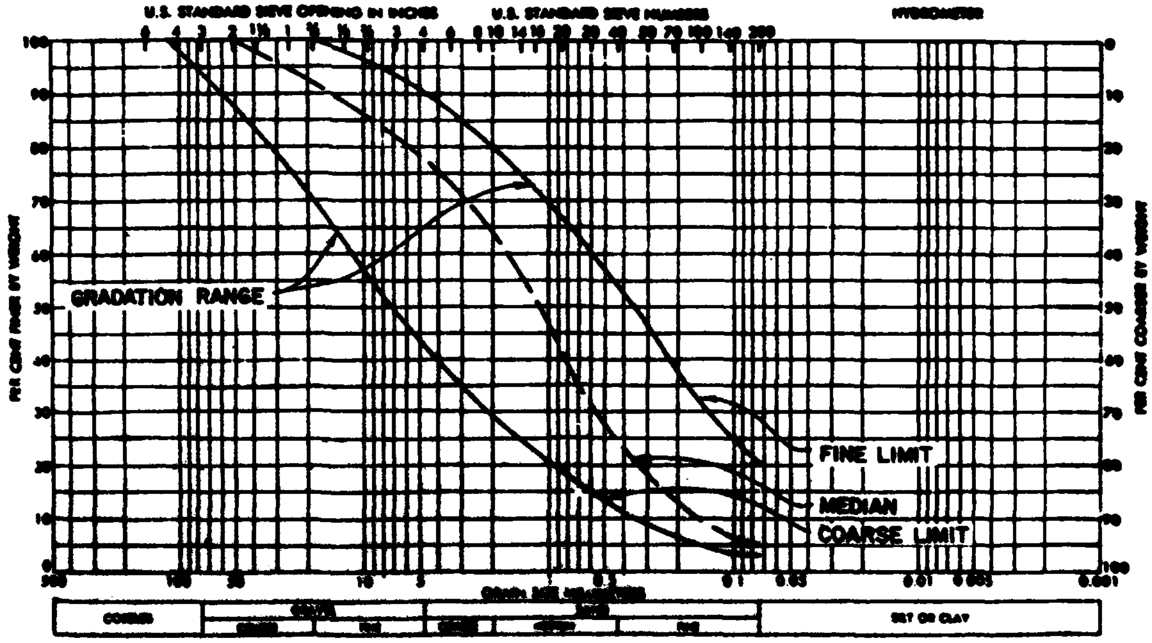
PLATE B-50

2

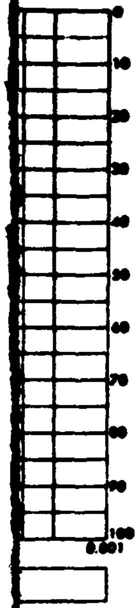
3

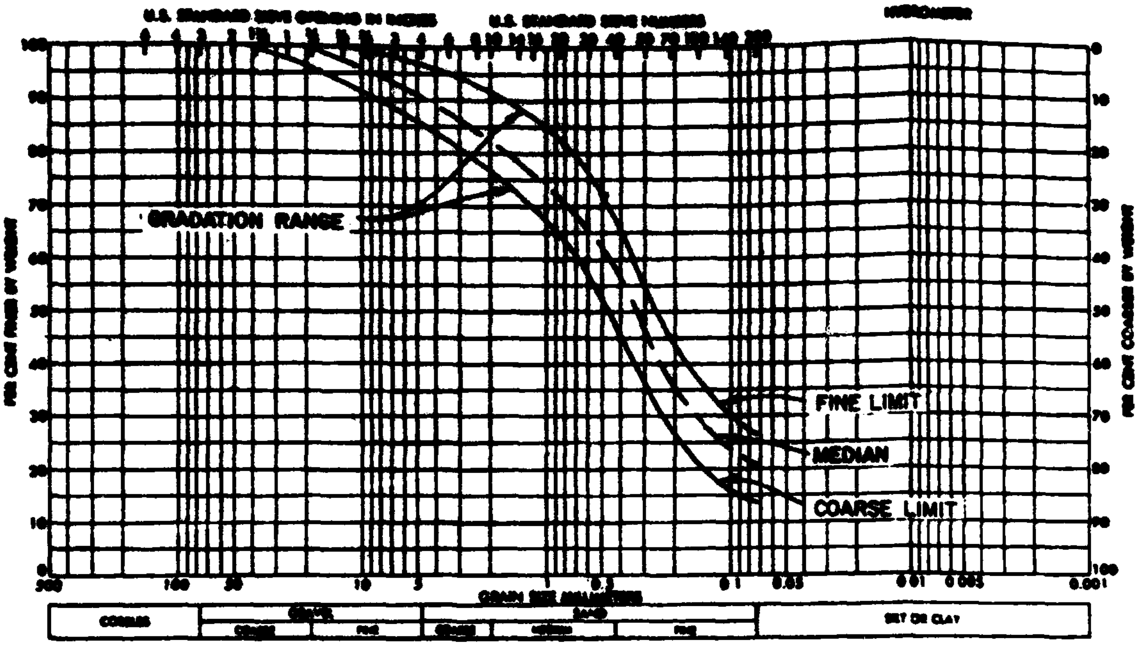


GRADATION CURVES FOR TYPE I MATERIAL
(Sands and Borderline Sands)

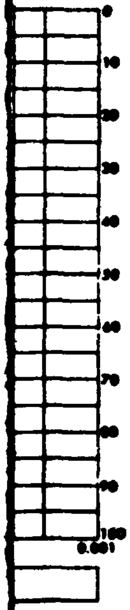


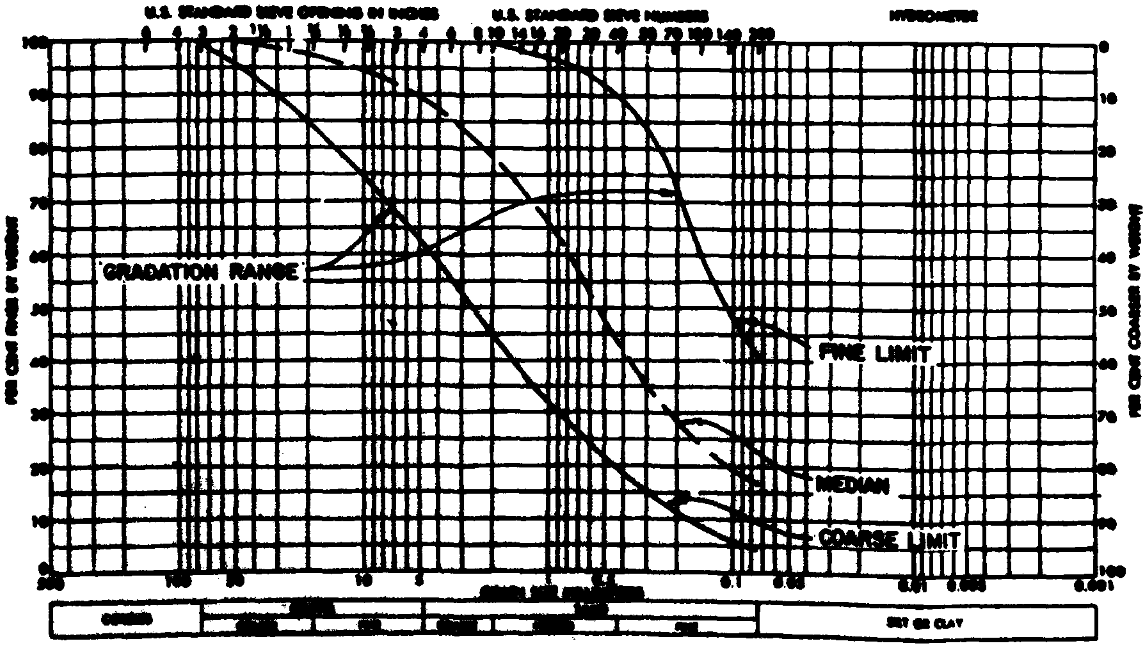
GRADATION CURVES FOR GRAVELLY TYPE I MATERIAL
(Gravelly Sands and Gravelly Borderline Sands)





GRADATION CURVES FOR TYPE 2 MATERIAL
(Silty Sands and Clayey Sands)

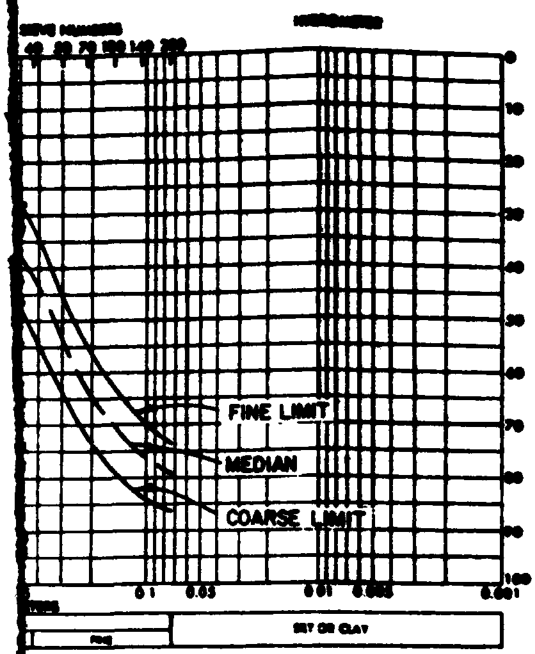




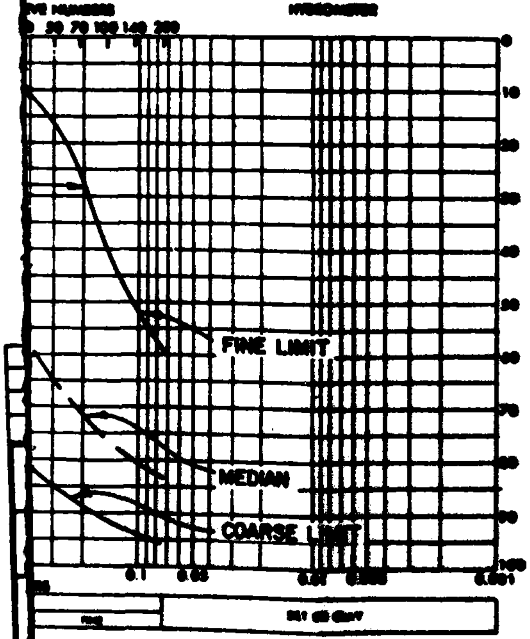
AL

GRADATION CURVES FOR GRAVELLY TYPE 2 MATERIAL
(Gravelly Silty Sands and Gravelly Clayey Sands)

1 2



TYPE 2 MATERIAL
ayey Sands)



ELLY TYPE 2 MATERIAL
ravelly Clayey Sands)

NOTE:

SEE PLATE B-45 FOR CROSS SECTION OF FOUNDATION

SYMBOL | DESCRIPTION | DATE | APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY
DRAWN BY
CHECKED BY

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

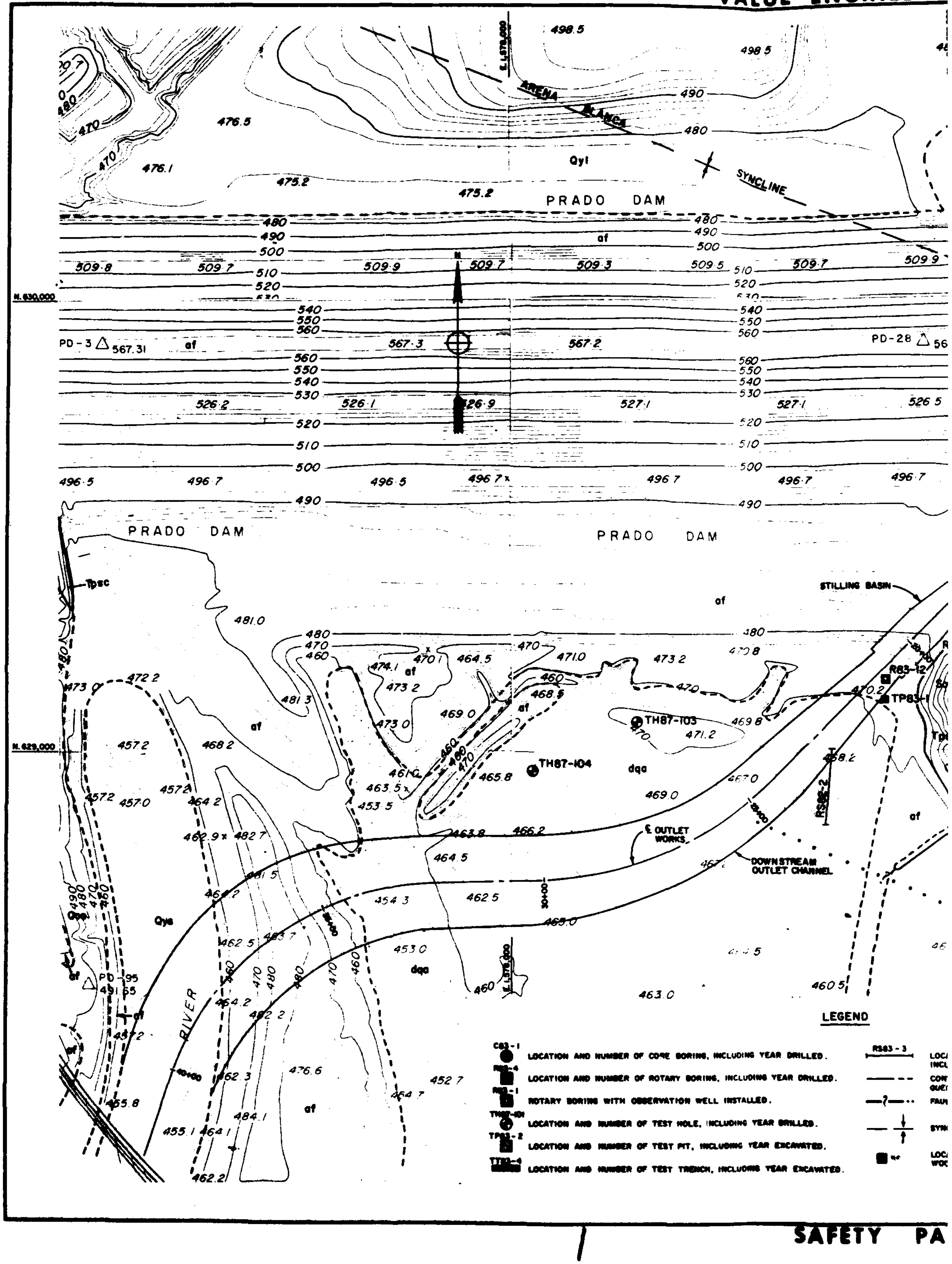
DAM FOUNDATION MATERIALS
GRADATION LIMITS

SUBMITTED BY
DATE APPROVED
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-51

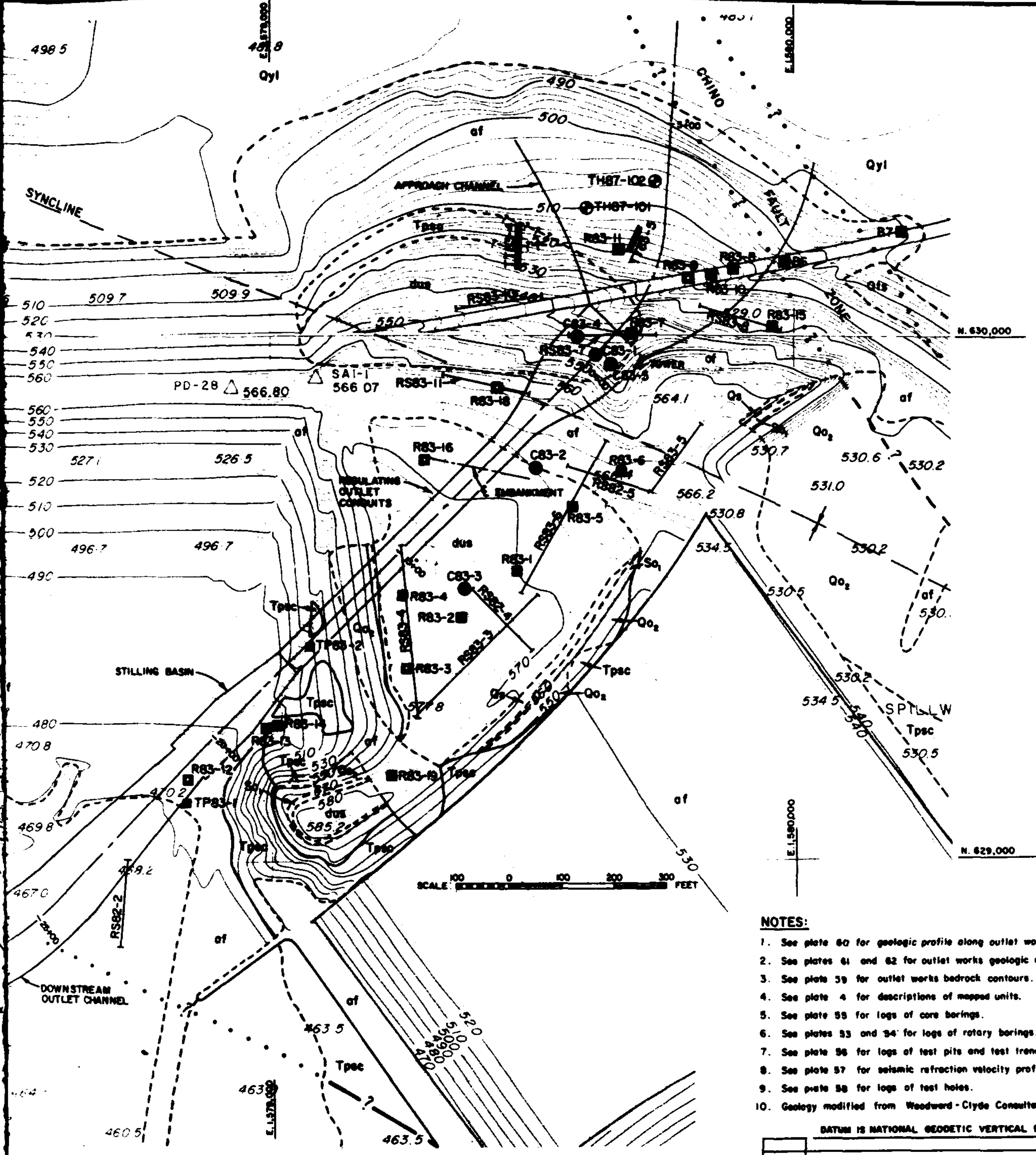
3

VALUE ENGINEERIN



SAFETY PA

VALUE ENGINEERING PAYS



NOTES:

1. See plate 60 for geologic profile along outlet works centerline.
2. See plates 61 and 62 for outlet works geologic cross sections.
3. See plate 59 for outlet works bedrock contours.
4. See plate 4 for descriptions of mapped units.
5. See plate 55 for logs of core borings.
6. See plates 53 and 54 for logs of rotary borings.
7. See plate 56 for logs of test pits and test trenches.
8. See plate 57 for seismic refraction velocity profiles.
9. See plate 58 for logs of test holes.
10. Geology modified from Woodward-Clyde Consultants (1980).

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

LEGEND

LUDING YEAR DRILLED.
NCLUDING YEAR DRILLED.
STALLED.
DING YEAR DRILLED.
NG YEAR EXCAVATED.
LUDING YEAR EXCAVATED.

RS83-3 ├──┤ LOCATION AND NUMBER OF SEISMIC REFRACTION SURVEY LINE, INCLUDING YEAR CONDUCTED.

—— - - CONTACT BETWEEN GEOLOGIC UNITS, DASHED WHERE INFERRED, QUERIED WHERE CONJECTURAL.

—?— · · FAULT, DASHED WHERE INFERRED, DOTTED WHERE CONCEALED.

—┼— SYNCLINE, DASHED WHERE INFERRED.

■ LOCATION AND NUMBER OF ROTARY BORING DRILLED BY WOODWARD-CLYDE CONSULTANTS (1980).

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

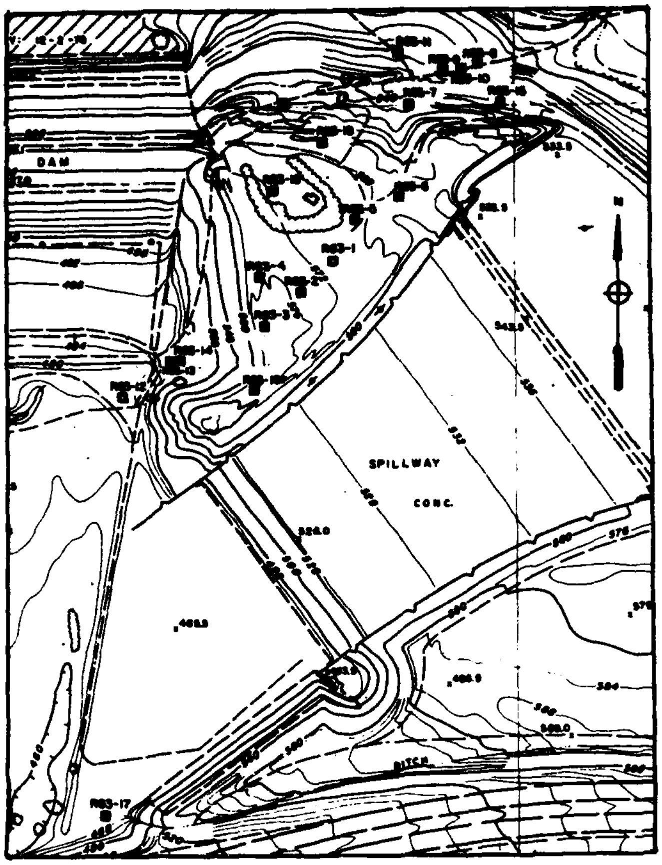
PRADO DAM
OUTLET WORKS
GEOLOGY AND PLAN OF EXPLORATION

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-52

SAFETY PAYS

12



LOCATION MAP

SCALE 100 0 100 200 300 400 500 FEET

GENERAL NOTES:

1. All R-series (rotary) holes were drilled with a CP-55 drill between February and April 1983.
2. Most holes were advanced thru the overburden using 8-inch flight augers. Samples for testing were taken from the auger cuttings.
3. Bedrock was sampled using either a split-spoon penetrometer or Pitcher sampler with 3-inch "Shelby" tube.
4. Some Pitcher samples were extruded in the field, were not tested and no sample number is shown.
5. Where no sample interval is shown on the log, the sample represents a "point" sample or very thin interval.
6. See plate 4 for descriptions of overburden classifications (after 1980 Fault Study Report by Woodward-Clyde Consultants).
7. Bedrock groupings are based upon visual appearance and mechanical analyses.

   Group A-B SANDSTONE: light grey, buff and orange; 15 to 25% low plastic silt to borderline silt-clay matrix; very fine to coarse sand, well graded; predominantly quartz, little mica; occasionally conglomeratic, thin layers of gravel and small cobbles; uncemented; dense; looses coherency in water, friable

   Group C SANDY SILTSTONE-SILTY SANDSTONE: brown; 35 to 50% low plastic silt matrix; very fine to medium grained sand, moderately well graded; micaceous to very micaceous; greasy luster; uncemented; very stiff to hard; looses coherency in water; air slakes

   Group D SANDY SILTSTONE: grey-tan; greater than 60% low plastic silt to borderline silt-clay matrix; very fine to fine grained sand, mostly very fine; uncemented; very dense; looses coherency in water; fine grained equivalent of Group E

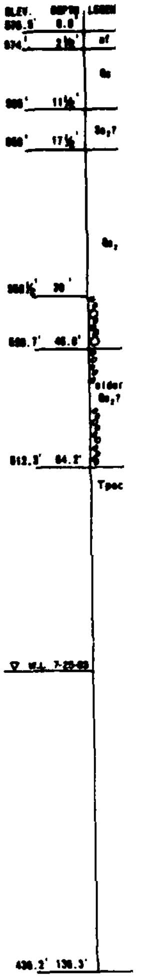
   Group E SANDSTONE: grey-tan and light to medium grey; 25 to 35% low plastic silt matrix; very fine to medium grained sand, mostly fine; micaceous; uncemented, occasional hard, $CaCO_3$ cemented concretionary zones or nodules; dense to very dense; looses coherency in water
8. See Table 18 for mechanical analyses of samples.
9. Water levels (W.L.) shown only for holes in which observation wells were installed.
10. See plate 22 for legend and outlet works plan.

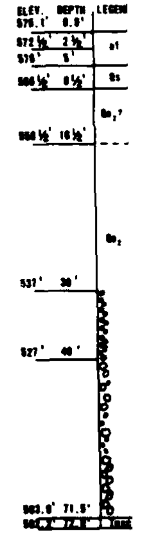
R83-1

ELEV.	DEPTH	LEGEND	SAMPLE NO.	DESCRIPTION
[illegible]	0.0			
		af		silty gravelly sand: light brown; moderately loose
562'	8'			
		Qa₃?		clayey gravelly sand: medium reddish brown; 20-25% gravel to 3-inch maximum
557'	13'			
		Qa₂		gravelly sand-silty sand: light brown; well graded
			1	
541'	29'			amount and size of gravel increases below 29'
			2	
527'	43'			larger gravel and cobbles, mostly to 6-inch maximum below 43'
				material just above bedrock contact is gravelly sand: grey with limonite staining, fine to coarse sand; sub-rounded gravel to 1½" observed
515'	55'		3	
		Tpac		
▽ W.L. 7-25-83				cuttings and drilling action indicate CONGLOMERATIC SANDSTONE
	76'			possible contact between bedrock types at 76'
	82'		4	SANDSTONE: grey-white, "salt and pepper" appearance, Group E
				contact at 82'
			5	SILTY SANDSTONE: medium grey-brown; Group C
			6	SANDY SILTSTONE: light brown; very micaceous; Group C
	119'			contact at 119'
438.7'	131.2'		7	SANDSTONE: medium grey; Group E

R83-7

ELEV.	DEPTH	LEGEND	SAMPLE NO.	DESCRIPTION
540.0'	0.0'			
				clayey silty sand: medium brown; moderately loose; soil zone
535½'	4½'			
		af?		sandy clay: dark brown; moderately soft; moist
528'	12'			
			25	gravelly clayey sand: tan; moderately loose; moderately well graded to 0.75" pea gravel
524'	16'			
				sand: tan; moderately loose; fine to medium grained; occasional clay pods; increasing gravel at 19'
519'	21'	Qa₂		
			26	
▽ W.L. 7-29-83				gravelly silty sand: tan to brown; 30% sub-rounded gravel to 1½" maximum size; sand mostly fine to medium
505.7'	34.3'			
		Tpsc	27	SANDY SILTSTONE: grey-brown; Group D
	40'			possible contact between bedrock types at 40'
				SANDSTONE: grey; hard, well $CaCO_3$ cemented concretions; probable Group E
				SANDSTONE: same as above
				contact?
			28	SANDY SILTSTONE: grey-brown; micaceous; Group D
				contact?
			29	SILTY SANDSTONE: brown; irregular fat-clay filled fracture? at 58.4 to 58.6'; apparent bedding dips 15°; occasional small calcareous nodules; Group C
				contact?
				SANDSTONE: grey-tan; $CaCO_3$ cemented nodules to 1"; Group E
			30	SANDSTONE: grey-tan; Group E
	81'			contact at 81'
			31	SANDY SILTSTONE: brown; possible bedding plane shear 83.9-83.6'; Group C
	88'			contact at 88'
			32	SANDSTONE: grey-tan; bedding indistinguishable; Group E
442.85'	97.15'		33	SANDSTONE: grey-tan; possible bedding dips 10 to 25°; Group E





DESCRIPTION
light brown; moderately loose
medium reddish brown; 20-25%
silt: light brown; well graded
gravel increases below 20'
bles, mostly to 6-inch maximum
drock contact is gravelly sand:
staining, fine to coarse sand; sub-
observed
action indicate CONGLOMERATIC SANDSTONE
en bedrock types at 76'
"salt and pepper" appearance, Group E
en grey-brown; Group C
t brown; very micaceous; Group C
y, Group E

PTION
dium brown; moderately loose; soil
n; moderately soft, moist
tan; moderately loose; moderately
pea gravel
loose; fine to medium grained;
increasing gravel at 10'
tan to brown; 30% sub-rounded
size, sand mostly fine to medium
brown; Group B
en bedrock types at 40'
well CaCO₃ cemented concretions;
ve
brown; micaceous, Group B
; irregular fat-clay filled fracture?
ent bedding dips 15°; occasional small
up C
CaCO₃ cemented nodules to 1"; Group E
roup E
possible bedding plane shear 83.5-
dding indistinguishable; Group E
ossible bedding dips 10 to 20°; Group E

R83-3

ELEV. 576.5'	DEPTH 0.0	LEGEND	SAMPLE NO.	DESCRIPTION
574'	2½'	af		gravelly sand: golden brown; loose
565'	11½'	Qs	11	sandy silt: brown; moderately soft; slightly clayey and plastic; scattered gravel 7.6-11.0'
559'	17½'	Qo_1?		gravelly clayey silt: brown; gravel to 1½" maximum size
		Qo_1		gravelly sand: medium brown; moderately loose; well graded, fine sand to 1" gravel; damp
546½'	30'			
535.7'	40.8'			coarser gravel and cobbles between 30-40.8'
		older Qo_1?	12 13 14 15	gravelly sand: grey with minor limonite staining; fresh to severly weathered generally granitic clasts to 3+"; abundant quartz and mica; horizontally layered; highly micaceous silty sand at 60½'
512.3'	64.2'			
		Tpsc	16	CONGLOMERATIC SANDSTONE: light orange-brown; pebbles to 2.5"; Group A-B
▽ W.L. 7-29-83			17	SANDSTONE: light yellow-grey; horizontal color banding (weathering?); faint indication of bedding dips 60°; Group A-B
			18	SANDSTONE: orange-white, mottled; occasional brown silt pods; Group A-B
438.2'	138.3'		19	SANDSTONE: grey; Group A-B

R83-4

ELEV. 575.1'	DEPTH 0.0'	LEGEND	SAMPLE NO.	DESCRIPTION
572½'	2½'	af		gravelly sand: light brown; loose
570'	5'			silty sand: brown; fine grained sand
566½'	8½'	Qs	20	sandy silt: light to medium reddish brown; sand very fine to fine
		Qo_1?	21	gravelly silty sand: medium brown; mostly coarse sand and pea gravel, occasional gravel to 2" maximum dimension
556½'	18½'			
		Qo_1	22	silty sand: medium brown; well graded; approximately 10% pea gravel; easily augered
537'	38'			significantly larger and more gravel below approximately 38'
527'	48'			occasional small boulders below 48'
				moderate drilling fluid circulation losses 67 to 67.5'
503.6'	71.5'			
[illegible]	[illegible]	Tpsc	23	CONGLOMERATIC SANDSTONE: yellow and white; pebbles to ½" Group A-B

VERTICAL SCALE: 1 INCH = 40 FEET

SCALE FEET

R83-2

ELEV. 571.8'	DEPTH 0.0'	LEGEND	SAMPLE NO.	DESCRIPTION
566½'	5½'	af		gravelly sand: grey-brown; fine sand to ½-inch gravel, well graded; clayier and darker brown below 2½'
565'	7'	Qs		sandy silt: light brown; very fine sand
553½'	18½'	Qo_1?	8	gravelly silty sand: light to medium brown; angular to sub-angular gravel to 3-inch maximum dimension; increasing sub-rounded gravel at 11'
		Qo_1	9	sand-silty sand: medium brown; well graded; 20% sub-rounded gravel to 1½", mostly ¾" and smaller
537'	35'		10	more gravelly below 35'
525'	47'			more and larger gravel and cobbles below 47'
518'	54'			probable bedrock: possibly CONGLOMERATIC SANDSTONE: grey
511.4'	60.5'	Tpsc		

Top of bedrock elevation based upon auger drilling action, refractive seismic survey and very slight indications from auger cuttings.

R83-5

ELEV. 568.1'	DEPTH 0.0'	LEGEND	SAMPLE NO.	DESCRIPTION
559'	9½'	af		silty gravelly sand: medium brown; 20% gravel, mostly to 1" maximum, occasionally to 3+"
541'	27½'	Qo_1		gravelly sand: light brown; well graded fine to coarse sand; 15% gravel to 2½" maximum
528'	40'			increased amount and size of gravel below 27½
515.4'	52.7'			heavy gravel, cobbles and small boulders below 40'
514.1'	54.0'	Tpsc	24	SANDSTONE: light grey-brown; very micaceous; Group E

Top of bedrock within 1' of elevation indicated; sampled with SPT, 100 blows for 3-inch penetration

R83-6

ELEV. 555.5'	DEPTH 0.0	LEGEND	SAMPLE NO.	DESCRIPTION
		af		brown gravelly sandy clay; compacted fill
515.5'	40.0'			concrete cutoff-wall encountered at 40.0'

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: DAL
DRAWN BY:
CHECKED BY: DAL

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

OUTLET WORKS
LOGS OF ROTARY BORINGS

LOCATION MAP

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-83

2

R 83-8

ELEV. DEPTH 513.5' 0.0'	LEGEND	SAMPLE NO.	DESCRIPTION
508½' 5'	af		gravelly sand: medium to light grey-brown; slightly silty; well graded fine sand to 3-inch gravel
506½' 7'			gravelly clayey sand: grey-brown
501½' 12'	Qts?		silt: rich brown; slightly sandy; soft; wet
494' 19½'			sandy silt: reddish brown; soft; wet; mostly fine to very fine sand, occasionally medium to coarse
482½' 31'	Qo₂		silty gravelly sand: brown; saturated
479½' 34'			more gravelly below 31'
476½' 37'			larger gravel and cobbles 34' to 36'
459' 54.5'	?	34	clayey sand: light grey to grey-green; medium density; occasional sub-angular to sub rounded gravel to 1½"; uncharacteristic of alluvium or bedrock encountered in other holes; possibly similar to bedrock encountered by Woodward-Clyde Consultants (1980) in boring B7

Hole drilled exclusively with 6-inch flight auger; no positive indications of bedrock to 54.5'.

R 83-9

ELEV. DEPTH 522.3' 0.0'	LEGEND	SAMPLE NO.	DESCRIPTION
513' 9½'	af		silty sand: grey-brown; loose; mostly fine to medium sands; slightly damp
506' 16'	Qts?		gravelly silty sand: rich brown; moderately loose; very fine grained sand to 12' then fine to coarse with gravel to 1½"
▽ W.L. 7-28-83 492' 30'	Qo₂?		gravelly clayey sand: multicolored, limonite staining; apparently chaotic assemblage of relatively fresh to extremely weathered gravel combined with traces of white to yellow-buff arcosic sandstone
	Tpsc	35	SANDSTONE: light grey-buff; occasional pebbles to ¼" some slightly weathered; Group A-B.
		36	CONGLOMERATIC SANDSTONE: same as above except very gravelly; heterolithic clasts; Group A-B.
		37	CONGLOMERATIC SANDSTONE: same as above
489.1' 33.2'		38	SANDSTONE: light grey-buff; occasional pebbles; Group A-B? relatively high percentage of fines, clayey matrix.

Actual bedrock contact is between 28.8 and 33.2'; arbitrarily set at 30'

R 83-10

ELEV. DEPTH 517.4' 0.0'	LEGEND	SAMPLE NO.	DESCRIPTION
512½' 5'	af		gravelly silty sand: reddish brown to brown; moderately loose; damp; gravel and siltier below 2'
507½' 10'			gravelly sand; grey brown; 10% gravel to ½" maximum
492½' 25'	Qts?		clayey silt: rich brown; slightly sandy with rare gravel to ½" maximum size; reddish-brown below 14' wet at 18'
	Qo₂?	39	silty sand: medium brown; saturated; occasional gravel to 1½"
482' 35½' 480' 37½'		40	gravelly sand; multicolored with limonite staining on some very weathered gravel clasts
476.9' 40.5'	Tpsc	41	SANDSTONE: light grey-buff; occasional pebbles, some weathered; [illegible] Group A-B.

Top of bedrock set at 37.5' based on drilling action and cuttings.

R 83-11

ELEV. DEPTH 519.4' 0.0	LEGEND	SAMPLE NO.	DESCRIPTION
515' 4½'	Qo₂?		silty sand: light brown; moderately loose
514' 5'			gravelly silty sand: light brown; occasional cobbles
510' 9½'	Tpsc	42	SANDSTONE: light grey to tan buff; Group E.

Top of bedrock identified by auger drilling action and cuttings; actual depth is estimated. Elevation verified by test trench TT 83-6 located nearby.

R 83-12

ELEV. DEPTH 471.4' 0.0'	LEGEND	SAMPLE NO.	DESCRIPTION
469' 2½'	Qya?		silty sand: brown
463½' 8'			sand: light brown; very fine to coarse, rare gravel to 1" maximum size
457½' 13'	Qys		silty sand: dark grey brown; moderately dense; approximately 5% gravel to ½"
454½' 17'			gravelly silty sand: dark grey, moist to wet
450½' 21'			silty sand: dark grey; loose; very fine to fine sand; wet
▽ W.L. 7-28-83 431½' 40'			silty sand: distinct medium grey; coarser sand and less silt than above; maximum 10% pea gravel; and more micaceous with depth cobbles 37 to 38.5'
417.2' 54.2'			sand: distinct medium grey color as above; loose; very fine to coarse grained; similar to silty sand above except coarser and cleaner; very easily augured
415.2' 56.2'	Tpsc	43	SANDSTONE: grey; predominantly quartz; Group A-B.

R 83-13

ELEV. DEPTH 484.8' 0.0	LEGEND	SAMPLE NO.	DESCRIPTION
479½' 5½'	af		gravelly sand: light brown

Unidentified obstruction at 5.5'; unable to penetrate with hardface bit on flight augers. Abandoned hole.

R 83-14

ELEV. DEPTH 486.0' 0.0'	LEGEND	SAMPLE NO.	DESCRIPTION
479½' 6½'	af?		gravelly sand: light to medium brown; very fine to coarse sand; occasional cobbles to 6" maximum size
477½' 8½'			sandy silt/silty sand: dark grey brown
473' 13'			clayey/silty sand: medium grey brown
466' 20' 464.3' 21.7'	Qo₂		gravelly silty sand: medium brown; most gravel to ¾" maximum size; more and larger gravel and cobbles below 20'
▽ W.L. 7-28-83 427.5' 58.5'	Tpsc	44	SANDSTONE: grey; occasional rounded pebbles; Group A-B.

R 83-15

ELEV. DEPTH 529.5' 0.0'	LEGEND	SAMPLE NO.	DESCRIPTION
521' 8½'	af		silty sand: light grey-brown to light brown; scattered gravel to ½" maximum size; increasing gravel below 5'; darker brown color below 7'
514½' 15'	Qts		gravelly, sandy silt; dark brown above 10', medium dark below 10; pea gravel to ⅜" maximum size
510½' 19' 504.3' 25.2'	Qo₂		gravelly sand: grey-brown increased cobbles and boulders to 20" maximum size from 19 to 25.2'
499.1' 30.4'	Qo₂		silty sand: brown; moderately dense to 25.2' then dense
498.2' 31.3'	Tpsc	46	SANDSTONE: grey-buff; Group A-B.

ELEV. DEPTH [illegible] 0.0'	LEGEND
[illegible] 1½'	af
[illegible] 2½'	Qya
[illegible] 12'	
[illegible] 16½'	
552' 18'	
549' 21'	
543' 27'	Qoa
532' 38'	
528' 42'	
524' 46'	
518.5' 51.5'	Tpsc
87'	
▽ W.L. 7-28-83	
92'	
100'	
110'	
453.8' 116.2'	

ELEV. DEPTH 466' 0.0	LEGEND
457' 9'	
446' 20'	
435' 30'	Qys
425' 40'	
414' 51'	
41 56'	

ELEV. DEPTH 576 0.0	LEGEND
564' 12'	
559' 17'	af
541' 35'	
538' 38'	Tpsc

RIPTION

ne to coarse; rare gravel to 1"

n; moderately dense; approximately

grey; moist to wet

se; very fine to fine sand.

m grey; coarser sand and less
% pea gravel; and more micaceous

color as above; loose, very fine
to silty sand above except coarser
ugered

ntly quartz; Group A-B

IPTION

t 5.5', unable to pentrate with
ers. Abandoned hole.

IPTION

edium brown; very fine to coarse
to 6" maximum size

h grey brown

grey brown

m brown; most gravel to 3/4
rger gravel and cobbles below

t rounded pebbles Group A-B.

IPTION

wn to light brown, scattered
increasing gravel below 5';

brown above 10', medium dark
" maximum size

ders to 20" maximum size from

ely dense to 28.2' then dense

A-B.

R 83-16

ELEV.	DEPTH	LEGEND	SAMPLE NO.	DESCRIPTION
570.0'	0.0'			
568½'	1½'	af		gravelly sand: light grey brown; loose; recent fill
567½'	2½'	dus		sandy silt/clay: dark grey; organic; soil zone
558'	12'	Qcs		gravelly sand silty sand: grey, grey-brown and brown
553½'	16½'			sand silty sand: brown; same as above except less gravel throughout
552'	18'			very gravelly with cobbles between 16.5 and 18'
549'	21'			
543'	27'			gravelly sand: light brown to brown; fine to coarse sand; 15% gravel and cobbles to 3" maximum size
				20-25% gravel and small cobbles below 27'
532'	38'			
528'	42'			less gravel below 38 to 42'
524'	46'			heavy gravel and cobbles 42 to 46'
518.5'	51.5'			less gravel below 46'
		Tpsc	46	SILTY SANDSTONE: medium brown; Group C
	67'			contact between bedrock types at 67'
∇ W.L. 7-25-83				
			47	SANDSTONE: grey white to tan; "salt and pepper" appearance; Group A-B
	92'			contact at 92'
			48	SANDY SILTSTONE: medium brown; Group C
	100'			contact at 100'
				cuttings indicate fine, grey, SANDSTONE; probably Group E
	110'			contact at 110'
453.8'	116.2'			SILTY SANDSTONE-SANDY SILTSTONE: medium brown with darker, softer and more clayey seams; interval 110.5' to 110.75' sheared, well developed slickensided surface dips 70°

R 83-17

ELEV.	DEPTH	LEGEND	SAMPLE NO.	DESCRIPTION
465'	0.0			sand, silty sand, sandy silt and silt: light to dark brown; alternating layers 1 to 2 thick; sand generally very fine to to fine grained
457'	8'	Qys		clayey-silty sand: medium brown; loose and spongy; very fine to occasionally medium grained; lense of medium grained sand at 12½; very moist
446'	20'			silty sand: grey brown; fine to coarse sand and occasional pea gravel; saturated and loose
436'	30'			sand: grey; well graded fine to coarse grained; loose and flowing
425'	40'		49	sand-silty sand: grey; simillar to above except more micaceous and generally finer grained
414'	51'		50	gravelly sand: grey; moderate density; fine to coarse grained sand and pea gravel
41	56'			

Bedrock not encountered.

R 83-19

ELEV.	DEPTH	LEGEND	SAMPLE NO.	DESCRIPTION
576	0.0	af		gravelly silty sand: medium to dark brown; moderately loose; damp; fill
564'	12'			sandy silt: light to medium brown; moderately loose; dry fill
559'	17'			silty gravelly sand: medium brown; medium density; dry fill
541'	36'	Tpsc		SANDSTONE; buff to orange; fine to medium grained, occasional gravel; Group A-B
538'	38'			

Fill logged from hollow-stem auger cutting and depths are approximate. Bedrock verified by drive sample (SPT)

R 83-18

ELEV.	DEPTH	LEGEND	SAMPLE NO.	DESCRIPTION
563.5'	0.0	af		silty gravelly sand: brown to grey brown; medium density; fine to coarse sand, sub angular gravel to 1" maximum size
551'	12½'	Qo₂		gravelly sand: light brown to brown; moderately loose to medium density; fine to coarse sand, gravel and cobbles to 4" maximum observed size; concentration of cobbles at 17-19' and 40-44'; gravelly 19-31.5'; sandy 31.5-40' and 44-47'
				Pitcher sample at 30.5' is sand: grey; well graded; medium density; occasional horizontal layering
516.5'	47.0'			
∇ W.L. 7-25-83		Tpsc	51	SANDSTONE: grey-brown; faint indications of bedding dip 65° to 70°, possible shear planes along micaceous partings at 48.0 to 48.2' dip 60°; Group E.
	60'			contact between bedrock types at 60'
			52	SANDY SILTSTONE: mottled grey reddish brown; Group C.
	89'			contact at 89'
			53	SANDSTONE: light to medium brown; finer grained at top of sample; Group E
	100.8'			contact at 100.8 to 101.1' dips 70°
			54	SANDY SILTSTONE: brown to reddish-brown; occasional very thin micaceous partings dip 65°; Group C
	116'			contact? at 116'
				possible change to fine, grey, SANDSTONE
	120			contact? at 120'
435.6'	127.9'		55	SILTY SANDSTONE: brown; Group C

NOTE:

1. SEE PLATE 53 FOR LOCATION OF BORINGS AND GENERAL NOTES.

SCALE 1 IN. = 10 FT.
10 0 10 20 30

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: DW
DRAWN BY: SBA
CHECKED BY: DW

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

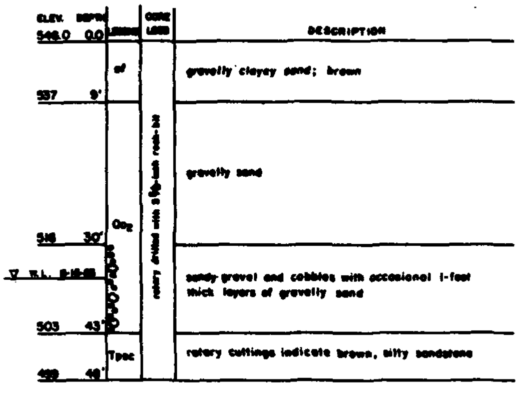
PRADO DAM

OUTLET WORKS
LOGS OF ROTARY BORINGS

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

2

C83-1



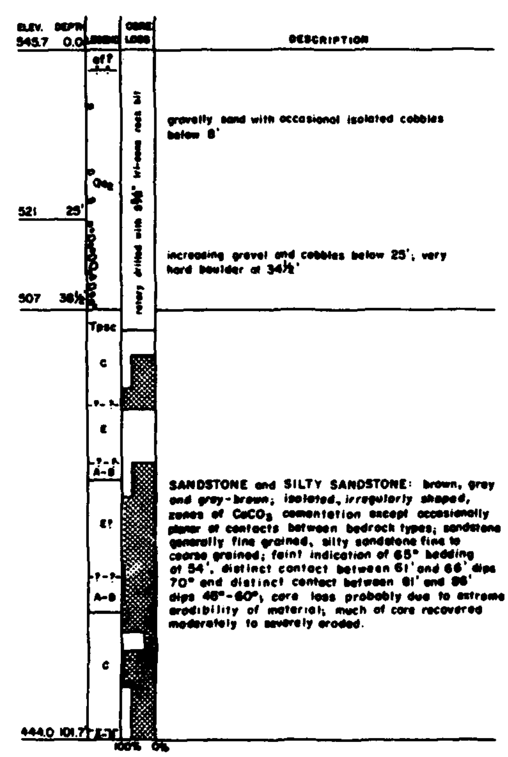
gravelly clayey sand; brown

gravelly sand

sandy gravel and cobbles with occasional 1-foot thick layers of gravelly sand

rotary cuttings indicate brown, silty sandstone

C83-5

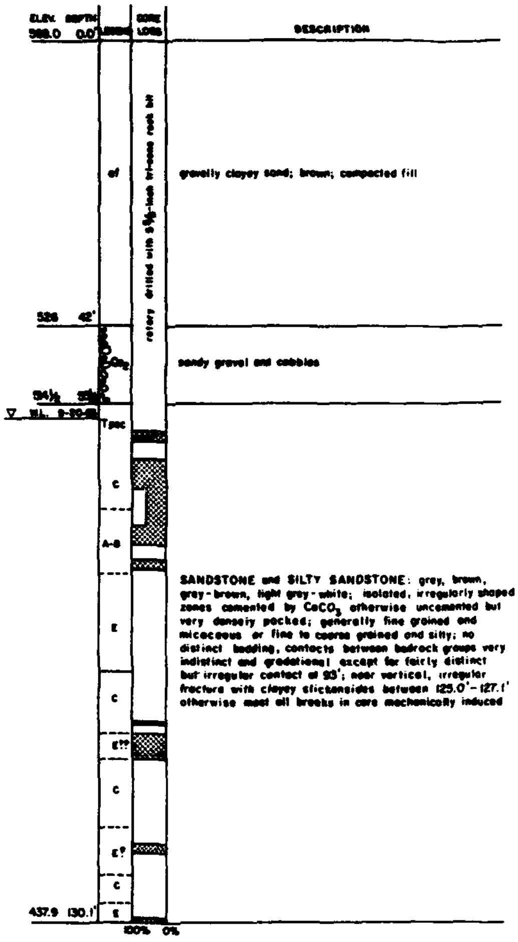


gravelly sand with occasional isolated cobbles below 8'

increasing gravel and cobbles below 25'; very hard boulder at 34½'

SANDSTONE and SILTY SANDSTONE: brown, grey and grey-brown; isolated, irregularly shaped, zones of $CaCO_3$ cementation except occasionally planar at contacts between bedrock types; sandstone generally fine grained, silty sandstone fine to coarse grained; faint indication of 65° bedding at 54', distinct contact between 61' and 66' dips 70° and distinct contact between 81' and 86' dips 45°-60°; core loss probably due to extreme erodibility of material; much of core recovered moderately to severely eroded.

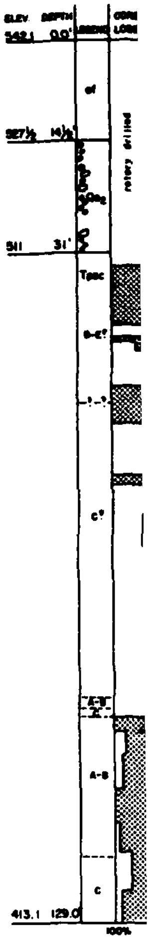
C83-2



gravelly clayey sand; brown; compacted fill

sandy gravel and cobbles

SANDSTONE and SILTY SANDSTONE: grey, brown, grey-brown, light grey-white; isolated, irregularly shaped zones cemented by $CaCO_3$ otherwise uncemented but very densely packed; generally fine grained and micaceous or fine to coarse grained and silty; no distinct bedding, contacts between bedrock groups very indistinct and gradational except for fairly distinct but irregular contact at 93'; near vertical, irregular fracture with clayey slickensides between 125.0'-127.1' otherwise most all breaks in core mechanically induced



NOTES:

1. C-series holes were drilled between 25 July-18 August 1983 by California Testing Labs using Failing 750, Mobil B61 and Longyear 44 drill rigs
2. Stabilized water levels were not measured in holes C83-3 thru C83-5 due to bentonite mud used during drilling and/or slow stabilization in the low permeability bedrock.
3. Hole C83-1 was abandoned after the first attempt to core inside PVC casing.
4. See plate 53 for description of bedrock groups shown in LEGEND column. Contacts between groups where dashed are gradational.
5. Holes C83-2 and C83-3 were cored using a conventional split-tube NX core barrel with face discharge bits.
6. Holes C83-4 and C83-5 were cored using an NQ wireline core barrel with face discharge bits.
7. Where specific depths of core loss can not be determined, the core percentage lost is shown as a scaled value (100% to 0%) for the interval drilled.
8. See plate 52 for legend and outlet works plan.

SCALE

E ENGINEERING PAYS

C83-

sand

gravel and c

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ncemented but
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silty; no
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lly distinct
, irregular
n 125.0'-127.1'
ically induced.

3 by California
44 drill rigs.
hru C83-5 due
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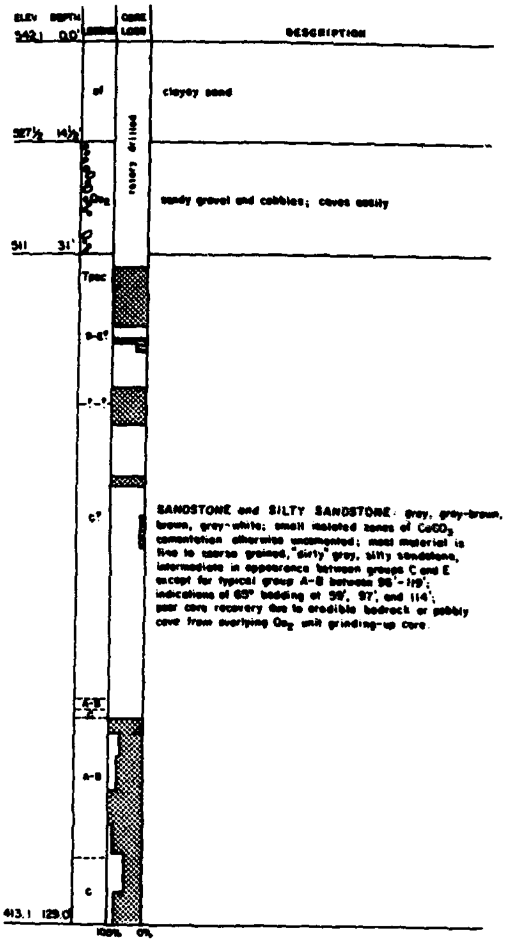
inside PVC casing
EGEND column
split-tube NX
core barrel
e core percentage
rilled

ATION

C83-4

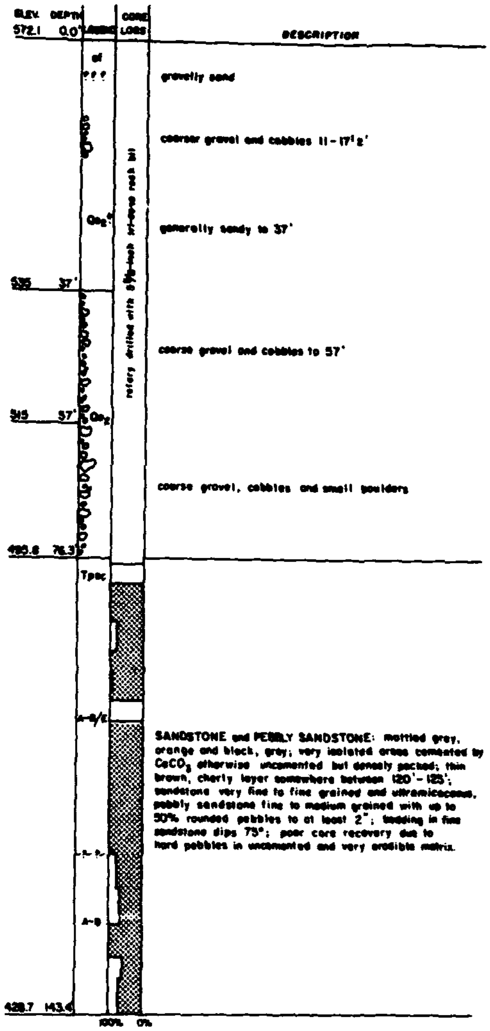


clayey sand

sandy gravel and cobbles; caves easily

SANDSTONE and SILTY SANDSTONE: grey, grey-brown, brown, grey-white; small isolated zones of $CaCO_3$ cementation otherwise uncemented; most material is fine to coarse grained, "dirty" grey, silty sandstone, intermediate in appearance between groups C and E except for typical group A-B between 96'-119'; indications of 65° bedding at 59', 97', and 114'; poor core recovery due to erodible bedrock or pebbly cave from overlying Qo_2 unit grinding-up core.

C83-3



gravelly sand

coarse gravel and cobbles 11-17½'

generally sandy to 37'

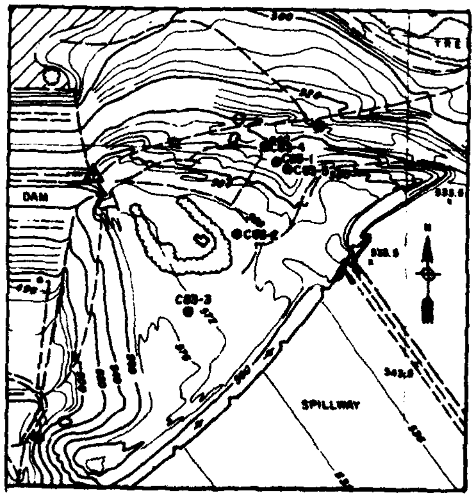
coarse gravel and cobbles to 57'

coarse gravel, cobbles and small boulders

SANDSTONE and PEBBLY SANDSTONE: mottled grey, orange and black, grey; very isolated areas cemented by $CaCO_3$ otherwise uncemented but densely packed; thin brown, cherty layer somewhere between 120'-125'; sandstone very fine to fine grained and ultramicaceous, pebbly sandstone fine to medium grained with up to 50% rounded pebbles to at least 2"; bedding in fine sandstone dips 75°; poor core recovery due to hard pebbles in uncemented and very erodible matrix.

SCALE: 1 IN. = 10 FT.

SCALE 10 0 10 20 30 FEET



LOCATION MAP

SCALE 100 0 100 200 300 400 500 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY
DRAWN BY
CHECKED BY

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
LOGS OF CORE BORINGS
LOCATION MAP

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET

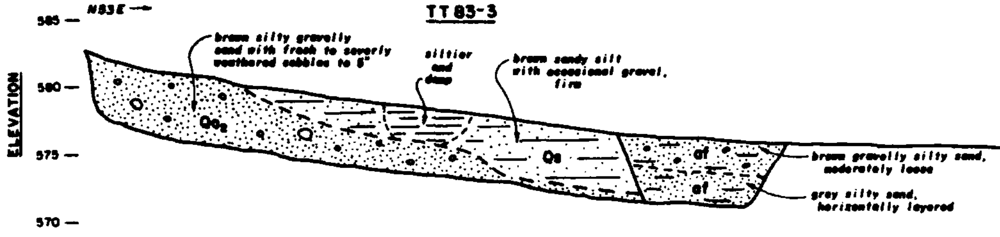
PLATE B-66

SAFETY PAYS

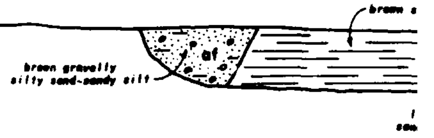
1

2

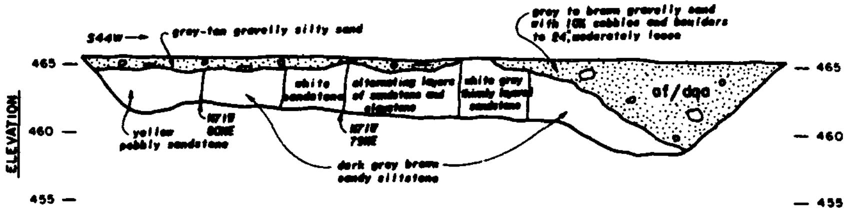
TT 83-3



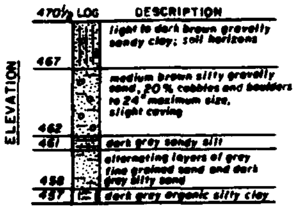
TT 8



TT83-1

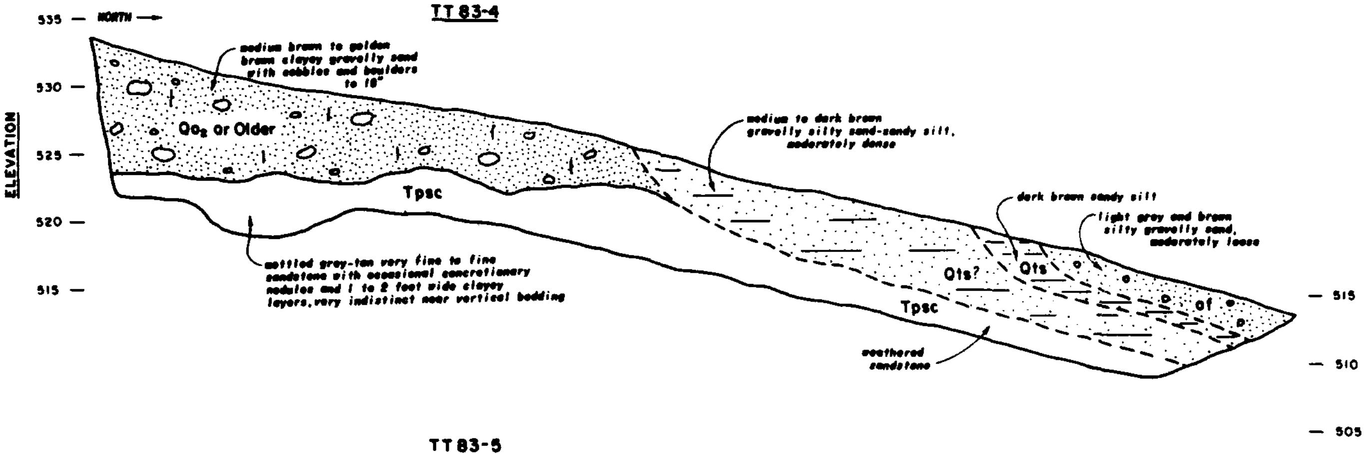


TP 83-1

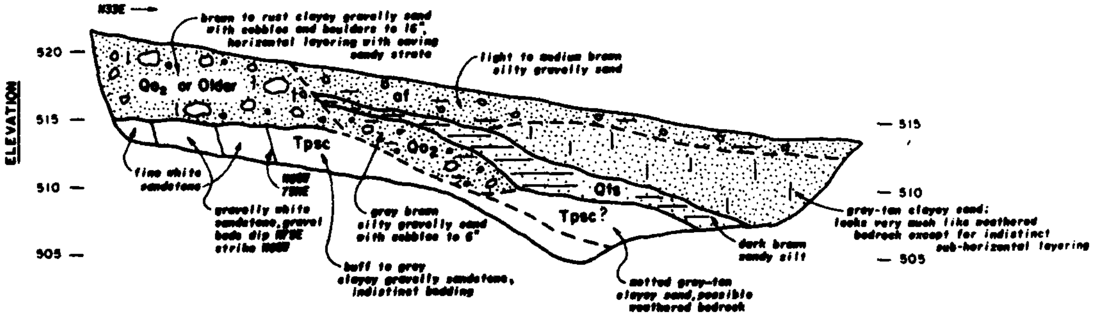


ELEVATION	DESCRIPTION
470½–467	light to dark brown gravelly sandy clay; soil horizons
467–462	medium brown silty gravelly sand, 20% cobbles and boulders to 24" maximum size, slight caving
461	dark grey sandy silt
458	alternating layers of grey fine grained sand and dark grey silty sand
457	dark grey organic silty clay

TT 83-4



TT 83-5



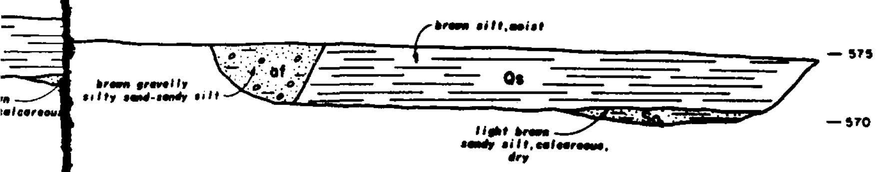
NOTES:

1. ALL TRENCHES AND PITS
2. TEST TRENCHES TT83-1
   TP83-1 AND TP83-2 EX
3. TEST TRENCHES TT83-3
   1-2 JUNE 1983.
4. MAPPED UNIT SYMBOLS
   PRADO DAM, WOODWARD-
5. ALL SOILS WERE VISUA
6. SEE PLATE 52 FOR LE

ALUE ENGINEERING PAYS

LOG

TT 83-2



TP 83-1

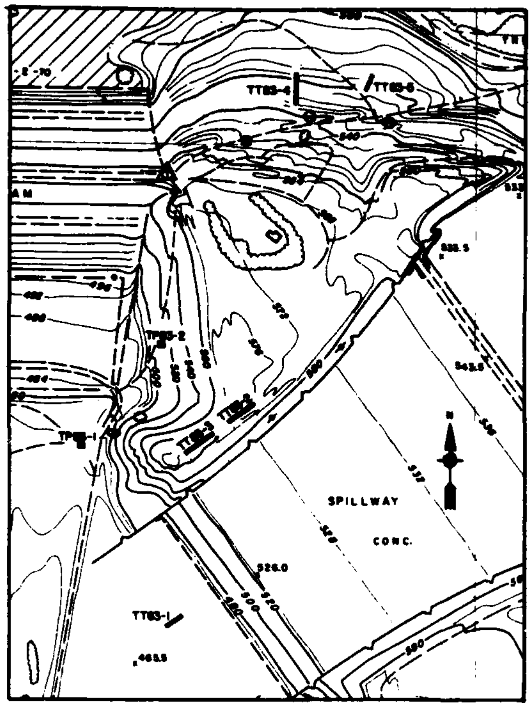
ELEVATION

470½	LOG	DESCRIPTION
		light to dark brown gravelly sandy clay; soil horizons
467		medium brown silty gravelly sand, 20% cobbles and boulders to 24" maximum size, slight caving
462		
461		dark grey sandy silt
		alternating layers of grey fine grained sand and dark grey silty sand
458		
457		dark grey organic silty clay

TP 83-2

ELEVATION

515	LOG	DESCRIPTION
		brown silty gravelly sand, moderately loose; fill
505½		



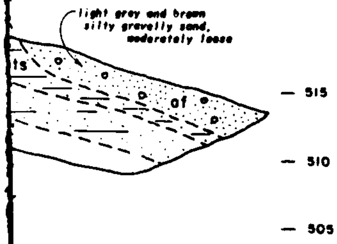
LOCATION MAP

SCALE 100 0 100 200 300 400 500 FEET

LEGEND

╲	CONTACT BETWEEN MAPPED UNITS
╲	BEDROCK BEDDING PLANES
╲ ╲	APPROXIMATE OR INDISTINCT CONTACT
af	ARTIFICIAL FILL
dqa	DISTURBED ALLUVIUM
Qts	DISSECTED YOUNGER SILT DEPOSITS
Qs	WIND BLOWN SILT
So_1	SOIL DEVELOPED ON OLDER ALLUVIAL, FINE-GRAINED FLUVIAL DEPOSITS
Qo_2	OLDER ALLUVIAL COARSE-GRAINED FLUVIAL DEPOSITS
Tpsc	PUENTE FORMATION, SYCAMORE CANYON MEMBER
||||	CLAY
≡	SILT
•ₒ	GRAVEL
⁘	SAND
≈	ORGANICS

rk brown sandy silt



TED WITH BA
3-2 AND TES
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83-5 EXCAVA

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NOTES:

1. ALL TRENCHES AND PITS EXCAVATED WITH BACKHOE.
2. TEST TRENCHES TT83-1 AND TT83-2 AND TEST PITS TP83-1 AND TP83-2 EXCAVATED ON 11-12 JANUARY 1983.
3. TEST TRENCHES TT83-3 THRU TT83-5 EXCAVATED ON 1-2 JUNE 1983.
4. MAPPED UNIT SYMBOLS AFTER FAULT STUDY REPORT FOR PRADO DAM, WOODWARD-CLYDE CONSULTANTS, JULY 1980.
5. ALL SOILS WERE VISUALLY CLASSIFIED.
6. SEE PLATE 52 FOR LEGEND AND OUTLET WORKS PLAN.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: DWL
DRAWN BY: gBa
CHECKED BY: WL

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
LOGS OF TEST TRENCHES AND TEST PITS
LOCATION MAP

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

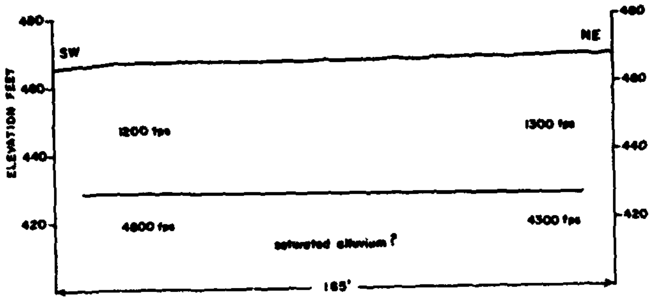
PLATE [illegible]

SAFETY PAYS

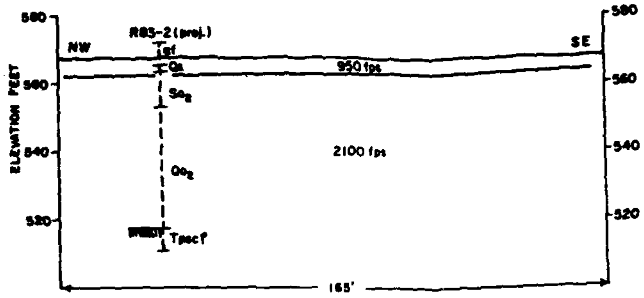
2

VALUE ENGINEERING

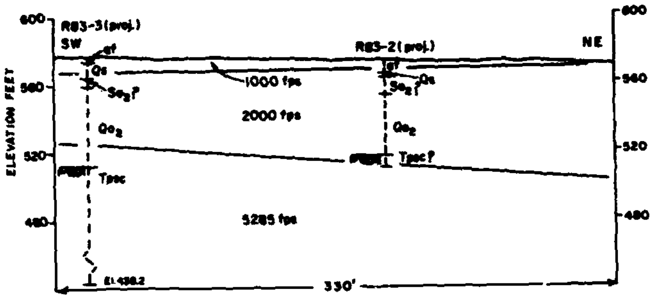
RS82-2



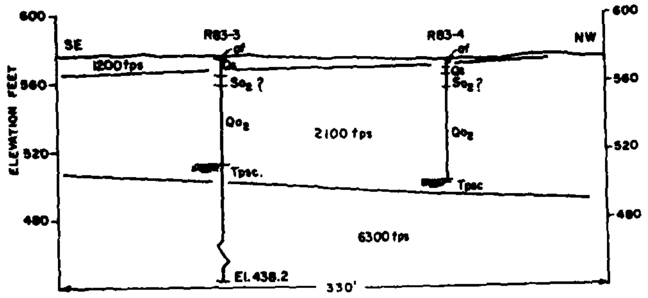
RS82-4



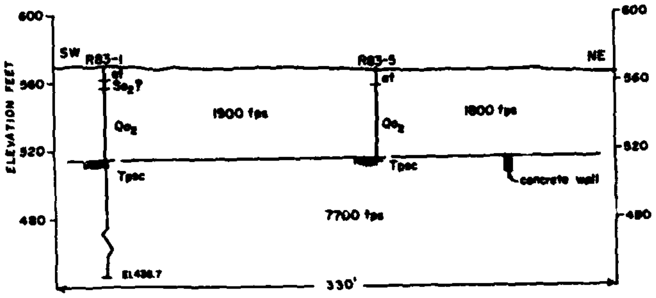
RS83-3



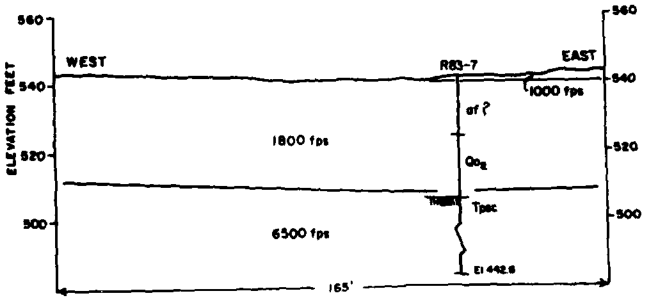
RS83-4

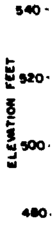


RS83-6



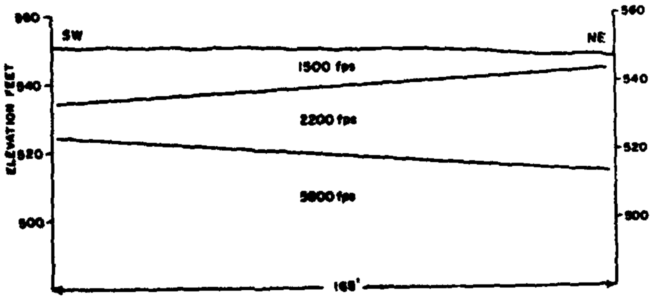
RS83-7

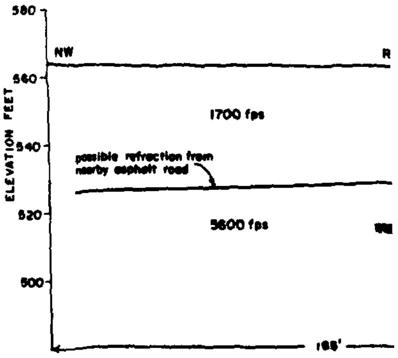




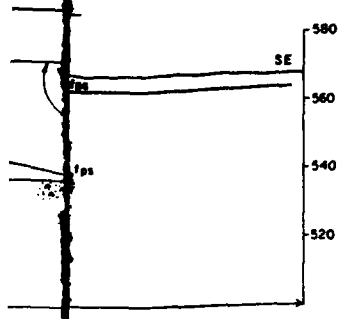
RS83-11

RS83-10

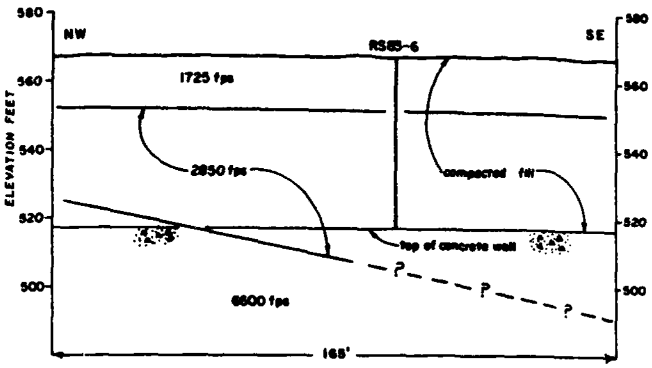


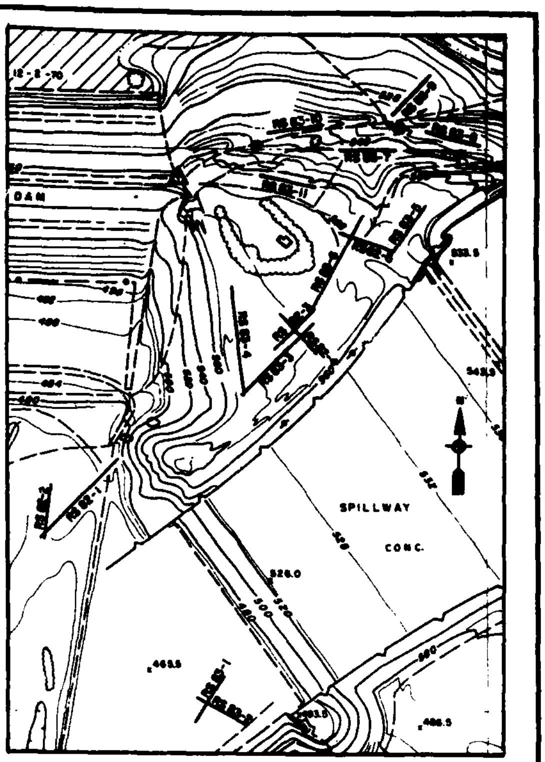


SAFETY PAY



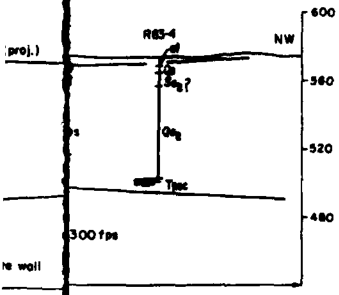
RS82-5



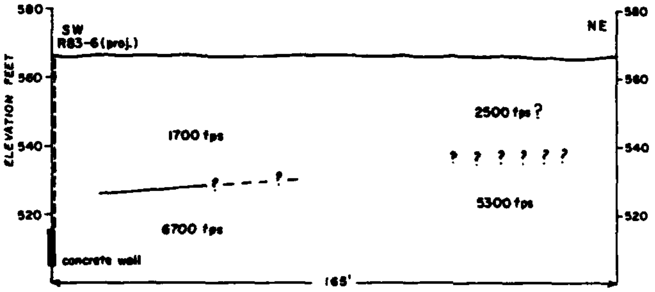


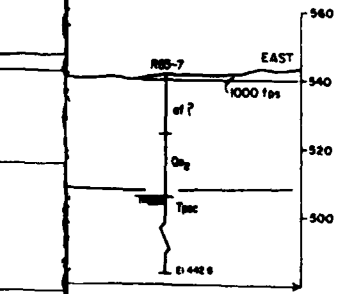
LOCATION MAP

SCALE 100 0 100 200 300 400 500 FEET

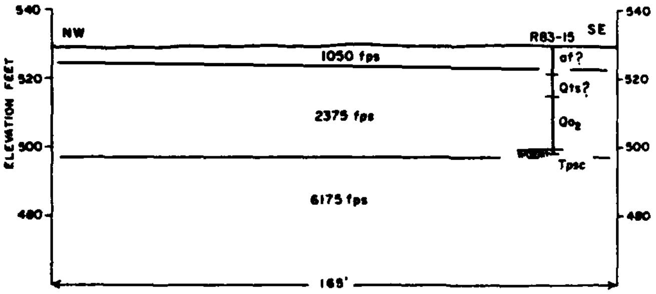


RS83-5

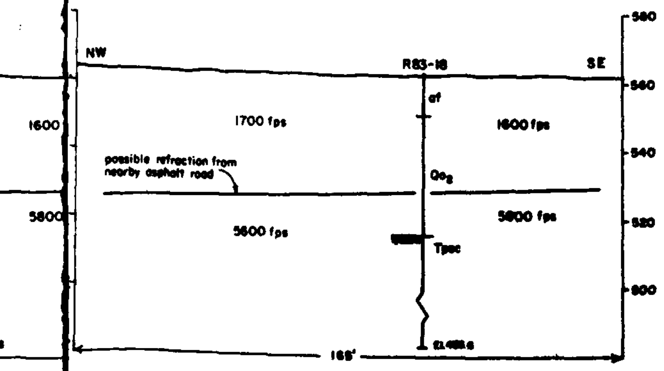




RS83-8



RS83-11



NOTES:

1. LINE RS82-1 YIELDED AN ASYMMETRICAL TIME-DISTANCE PLOT INDICATIVE OF A STEEPLY DIPPING BEDROCK SURFACE AT THE NORTHEAST END OF THE LINE. NO QUANTITIVE DEPTH CALCULATIONS WERE ATTEMPTED.
2. NO SIGNIFICANT VELOCITY BREAKS WERE RECORDED FOR LINE RS82-3. THE TIME-DISTANCE PLOT INDICATED VELOCITIES OF 1800 TO 2200 FEET PER SECOND TO A DEPTH OF 45 TO 60 FEET (ASSUMING BEDROCK VELOCITIES OF 3500 AND 6000 fps REPECTIVELY). SEE PROFILE FOR LINE RS82-4.
3. LINES RS83-1 AND RS83-2 WERE LAID OUT ON OUTCROPPING BEDROCK DOWNSTREAM FROM THE SPILLWAY. THEY INDICATED A P-WAVE VELOCITY OF 5750 FPS IN THE DIRECTION OF THE STRIKE OF THE BEDS AND 3350 IN A PERPENDICULAR DIRECTION.
4. SEISMOGRAPH MALFUCTIONED WHILE SHOOTING SOUTHWEST END OF LINE RS83-9. THE TIME-DISTANCE PLOT FROM THE NORTHEAST END INDICATED A VERY HIGH (UP-SLOPE) VELOCITY OF 11,000 FPS AT A DEPTH OF APPROXIMATELY 35 FEET (ELEVATION 473+) BELOW THE NORTHEASTERLY SHOT POINT.
5. ALL RECORDS WERE OBTAINED USING A NIMBUS ES-1200 SEISMOGRAPH AND EXPLOSIVE ENERGY SOURCES.
6. REFRACTIVE SURVEYS 82-1 THRU 82-5 WERE CONDUCTED 15-16 DECEMBER 1982
7. REFRACTIVE SURVEYS 83-1 THRU 83-11 WERE CONDUCTED BETWEEN 10 JAN AND 20 MAR 1983.
8. SEE PLATES 53,54 FOR DETAILED LOGS OF ROTARY BORINGS R83-1,2,3,4, 5,6,7,15 AND 18.
9. SEE PLATE 52 FOR LEGEND AND OUTLET WORKS PLAN.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: DWL
DRAWN BY: DRV
CHECKED BY: WL

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
SEISMIC REFRACTION SURVEYS
LOCATION MAP AND VELOCITY
PROFILES

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09- ____ B- ____
DISTRICT FILE NO.
SHEET

2

TH87 - 101

EL510 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
2.5'	SC				65	29		[illegible]	CLAYEY SAND WITH GRAVEL; brown, moist, gravel to 3 in., few cobbles to 4 in., gravel in SPT shoe.
6.0'	SM-SC		20	12	66	11			SAND WITH CLAY AND GRAVEL; brown, dry, loose, gravel to 3 in., few cobbles to 8 in.
9.5'	SC		28	13	94	41		24	CLAYEY SAND; brown, moist, slightly cohesive, few gravel to 3/4 in., occasional cobble to 6 in.
	ML	6.4		NP	95	60			SANDY SILT; brown, moist, few gravel to 3/4 in.
		14.6		NP	94	50		13	wet, few gravel to 1 in.
				NP	96	59			
23.0'				NP	90	52			
	CL	16.6	27	10	98	63	112.6		SANDY CLAY; brown, wet, cohesive, occasional gravel to 1/2 in.
		18.4	32	15	99	74			
		21.2	36	19	99	83	[illegible]		brown to grey with rust streaks, very stiff, some organics, roots.
		21.9	35	19	100	73			occasional gravel to 3 in.
31.0'			27	9	99	57		R	stiff.
38.0'	SP-SC				96	9			SAND WITH CLAY AND GRAVEL; brown, wet, loose, some gravel to 3 in., few cobbles to 5 in.

TH87 - 102

EL507 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRI
	SC		38	17	83	47			CLAYEY SAND WIT moist, slightly gravel to 2 in.
			32	12	92	23		R	CLAYEY SAND; br slightly cohesi 2 in.
9.0'		9.2	33	13	90	30			
12.0'	SC-SM	100			96	30		19	SILTY CLAYEY SA slightly cohesi 2 in.
13.0'	ML			NP	94	59			SANDY SILT; dar cohesive, few g
	SC-SM	16.6			94	16	110.[illegible]		SILTY CLAYEY SA cohesive, few g
21.0'			23	7	73	15		8	SILTY CLAYEY SA brown, wet, gra
	CL	20.7	38	19	99	67			SANDY CLAY; bro streaks, moist, stiff, few grav
25.0'			37	21	100	72			
29.0'	SC		27	11	66	20			CLAYEY SAND; br gravel to 3/4 i to 8 in.
33.0'	SP-SC		23	7	59	8			SAND WITH CLAY wet, gravel to to 8 in.
37.5'	GP-GC		24	7	52	9			GRAVEL WITH CLA wet, gravel to cobbles to 8 in.
	SC		33	15	91	23			SANDSTONE; ligh tan, dry, mediu slightly cohesi sand, clay matri 2 in.; GROUP A-4
			35	17	90	26			
44'			34	16	74	16			increasing grav

TH87 -103

E1470 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
3.0'	SM			NP	100	21			SILTY SAND; brown, moist, loose, fine sand.
6.0'	SP-SM	14.1		NP	93	11			SAND WITH SILT; brown, moist, loose, fine to medium sand, few gravel to 1-1/2 in.
7.5'	SM			NP	100	49		6	SILTY SAND; grey, moist, loose, fine sand.
	ML			NP	100	67			SANDY SILT; brown, moist, loose, fine sand.
12.5'		16.6		NP	99	62			
	SM			NP	100	25		11	SILTY SAND; brown to grey, moist, loose, fine sand, thin silty clay lense recovered from shelby.
17.0'		3.7		NP	99	15		10	
20.0'	SP-SM			NP	100	7			SAND WITH SILT; grey with orange streaks, moist, loose, fine sand.
22.0'	SM			NP	100	13		14	SILTY SAND; brown to grey, moist, loose, grey silt lumps.
	SP			NP	86	2		30	SAND; brown to grey, moist, medium dense, medium sand, gravel to 3in.
29.0'		2.4	28	4	91	3			grey, some cobbles to 8 in.
	SM		28	4	88	28			SILTY SAND; grey, wet, cohesive, gravel to 1-1/2 in.
32.5'				NP	100	17			
	SP-SM			NP	98	6		[illegible]	SAND WITH SILT; brown to green, wet, dense, medium sand.
40.0'				NP	100	5		R	

TH87 - 104

E1466 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRI
	SM			NP	98	13			SILTY SAND; bro
				NP	99	27		17	occasional lump occasional cobb
10.0'				NP	100	39		21 9	sand becomes fi
15.0'	SP-SM			NP	98	5		36	SAND WITH SILT; medium sand, fe 3/8 in.
16.0'	SW-SM			NP	82	9			SAND WITH SILT; to 1/2 in.
17.0'	ML			NP	100	66			SANDY SILT; gre cohesive.
18.0'	SM			NP	99	22			SILTY SAND; gre silt lenses.
	SP-SM			NP	85	7			SAND WITH SILT to green, mediu to 3 in.
25.0'				NP	87	8			
	SP			NP	92	3			SAND WITH SILT; medium sand, se
30.0'				NP	89	2			SAND; brown to few gravel to 3 SAND WITH GRAVE medium sand, se

Hole terminated
boulder.

VALUE ENGINEERING PAYS

TH87-102

EL507 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	SC		38	17	83	47			CLAYEY SAND WITH GRAVEL; brown, moist, slightly cohesive, gravel to 2 in.
			32	12	92	23		11	CLAYEY SAND; brown to grey, moist, slightly cohesive, few gravel to 2 in.
9.0'		9.2	33	13	90	30			
12.0'	SC-SM	10.0			96	30		15	SILTY CLAYEY SAND; brown to grey, slightly cohesive, few gravel to 2 in.
13.0'	ML			NP	94	58			SANDY SILT; dark brown, moist, cohesive, few gravel to 1 in.
	SC-SM	16.6			94	16	110.8		SILTY CLAYEY SAND; brown, wet, cohesive, few gravel to 1 in.
21.0'			23	7	73	15		8	SILTY CLAYEY SAND WITH GRAVEL; brown, wet, gravel to 2 in.
	CL	20.7	38	19	98	87			SANDY CLAY; brown with grey streaks, moist, very cohesive, stiff, few gravel to 3/4 in.
25.0'			37	21	100	72			
29.0'	SC		27	11	88	20			CLAYEY SAND; brown, wet, few gravel to 3/4 in., some cobbles to 8 in.
33.0'	SP-SC		23	7	58	8			SAND WITH CLAY AND GRAVEL; brown, wet, gravel to 2 in., some cobbles to 8 in.
37.5'	GP-GC		24	7	52	9			GRAVEL WITH CLAY AND SAND; brown, wet, gravel to 1-1/2 in., some cobbles to 8 in.
	SC		33	15	91	23			SANDSTONE; light to medium grey to tan, dry, medium dense, uncemented, slightly cohesive, fine to coarse sand, clay matrix, some gravel to 2 in.; GROUP A-6.
			35	17	90	26			
44'			34	16	74	16			increasing gravel content.

TH87-104

EL466 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	SM			NP	98	13			SILTY SAND; brown, dry, loose.
				NP	99	27		17	occasional lump of hard dry silt, occasional cobble to 5 in.
10.0'				NP	100	39		21	sand becomes finer.
15.0'	SP-SM			NP	98	5		9 38	SAND WITH SILT; grey, fine to medium sand, few gravel to 3/8 in.
16.0'	SP-SM			NP	97	9			SAND WITH SILT; grey, few gravel to 1/2 in.
17.0'	ML			NP	100	66			SANDY SILT; grey with rust streaks, cohesive.
18.0'	SM			NP	99	22			SILTY SAND; grey to rust, thin silt lenses.
	SP-SM			NP	86	7			SAND WITH SILT AND GRAVEL; brown to green, medium sand, some gravel to 3 in.
25.0'				NP	87	8			
	SP			NP	92	3			SAND WITH SILT; brown to green, medium sand, some gravel to 3 in.
									SAND; brown to green, medium sand, few gravel to 3 in.
30.0'				NP	86	2			SAND WITH GRAVEL; brown to green, medium sand, some gravel to 3 in.

Hole terminated at 30 ft.-hit boulder.

NOTES:

1. TEST HOLES WERE DRILLED WITH A 24-INCH BUCKET AUGER IN APRIL 1987.
2. SEE PLATE 36 FOR LEGEND AND CLASSIFICATION SYSTEM.
3. SEE PLATE 52 FOR HOLE LOCATIONS.

SCALE: 1 IN. = 5 FT.

5 0 5 10 15

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

OUTLET WORKS

LOGS OF BUCKET AUGER HOLES

DATE APPROVED

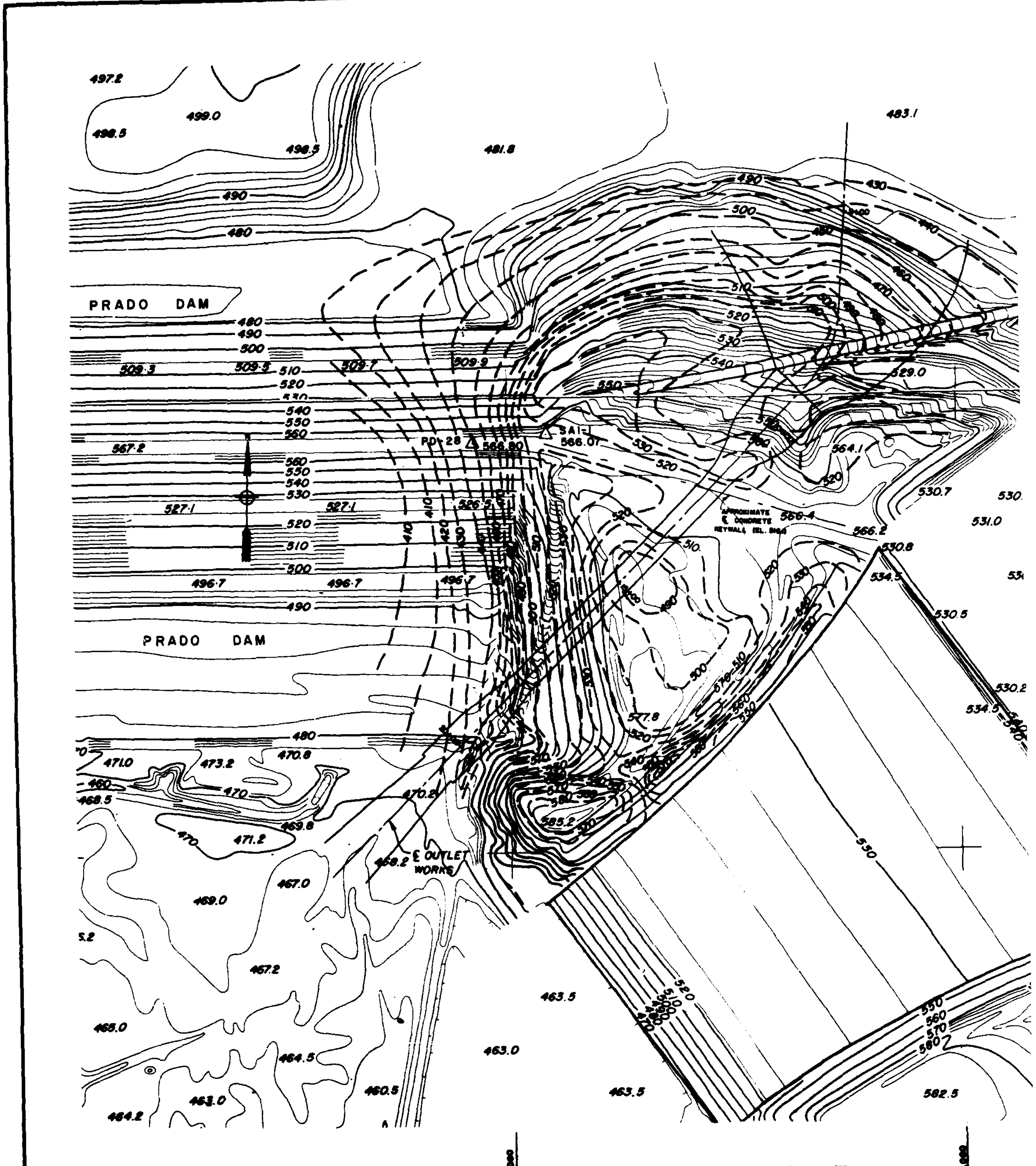
SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SAFETY PAYS

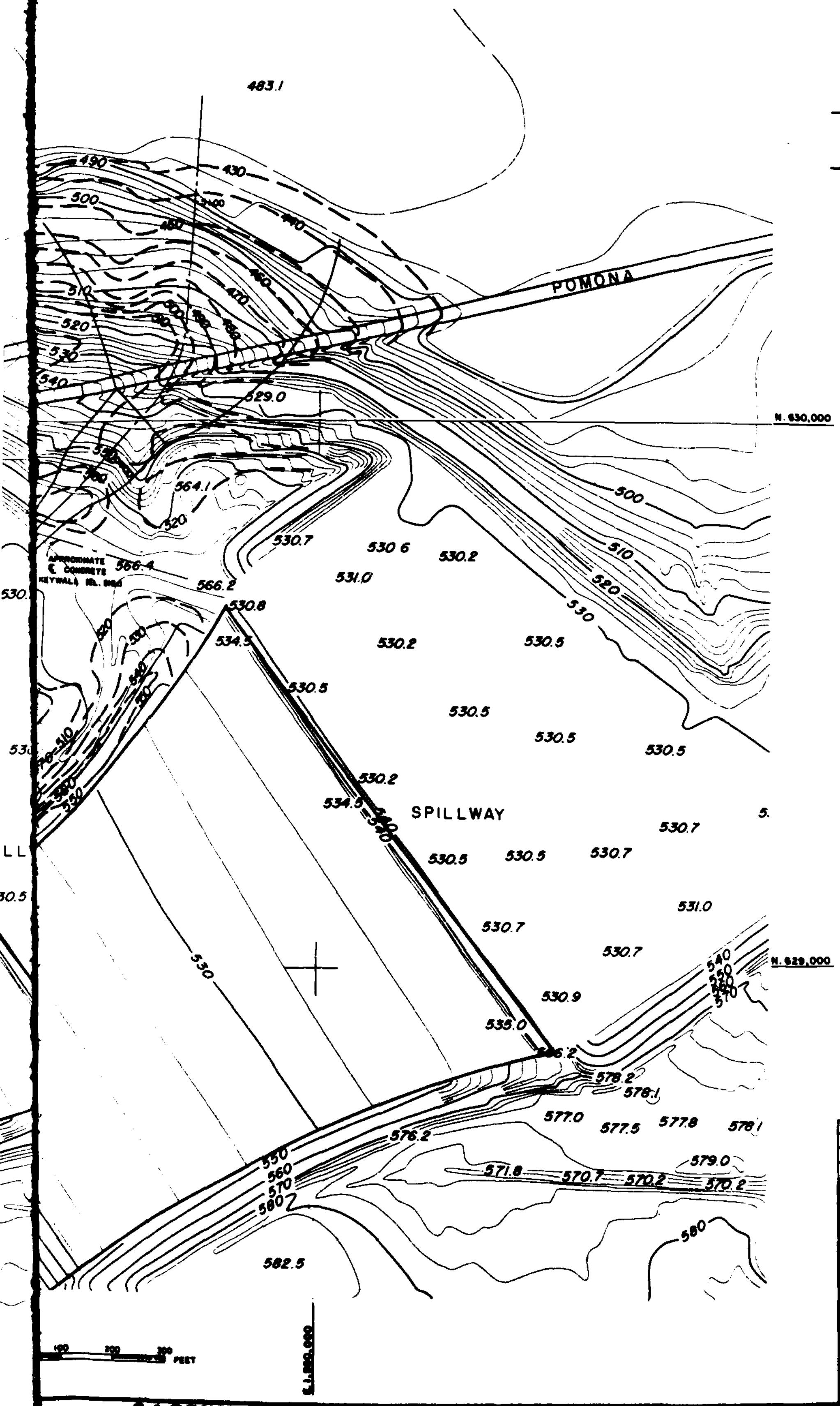
PLATE B-60

2


497.2
499.0
498.5
498.5
481.8
483.1
490
480
PRADO DAM
480
490
500
509.3
509.5
509.7
509.9
510
520
530
540
550
560
567.2
PD-28
566.80
SAI-1
566.07
560
550
540
530
527.1
527.1
526.5
520
510
500
496.7
496.7
496.7
490
PRADO DAM
410
410
420
430
529.0
564.1
530.7
531.0
APPROXIMATE
℄ CONCRETE
KEYWALL (EL. 566)
566.4
566.2
530.8
534.5
530.5
530.2
534.5
577.8
480
471.0
473.2
470.8
460
470
468.5
470.2
469.8
471.2
470
468.2
℄ OUTLET WORKS
467.0
469.0
467.2
465.0
463.5
464.5
463.0
460.5
463.5
463.0
464.2
585.2
550
550
560
570
580
582.5
SCALE 100 0 100 200 300 FEET

SAFETY PAYS

VALUE ENGINEERING PAYS



LEGEND

—520— CONTOUR LINE SHOWING EXISTING GROUND SURFACE ELEVATION IN FEET (1979)

– –500– – CONTOUR LINE SHOWING APPROXIMATE BEDROCK ELEVATION IN FEET, DASHED WHERE APPROXIMATE.

NOTES:

1. BEDROCK CONTOUR INTERVAL IS 10 FEET
2. BEDROCK ELEVATION CONTOURS DERIVED FROM CORPS OF ENGINEERS FIELD INVESTIGATIONS
3. SEE PLATE 52 FOR OUTLET WORKS GEOLOGY AND PLAN OF EXPLORATION.
4. SEE PLATE 60 FOR OUTLET WORKS GEOLOGIC PROFILE.
5. SEE PLATES 61 AND 62 FOR OUTLET WORKS GEOLOGIC CROSS SECTIONS.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

OUTLET WORKS

BEDROCK CONTOURS

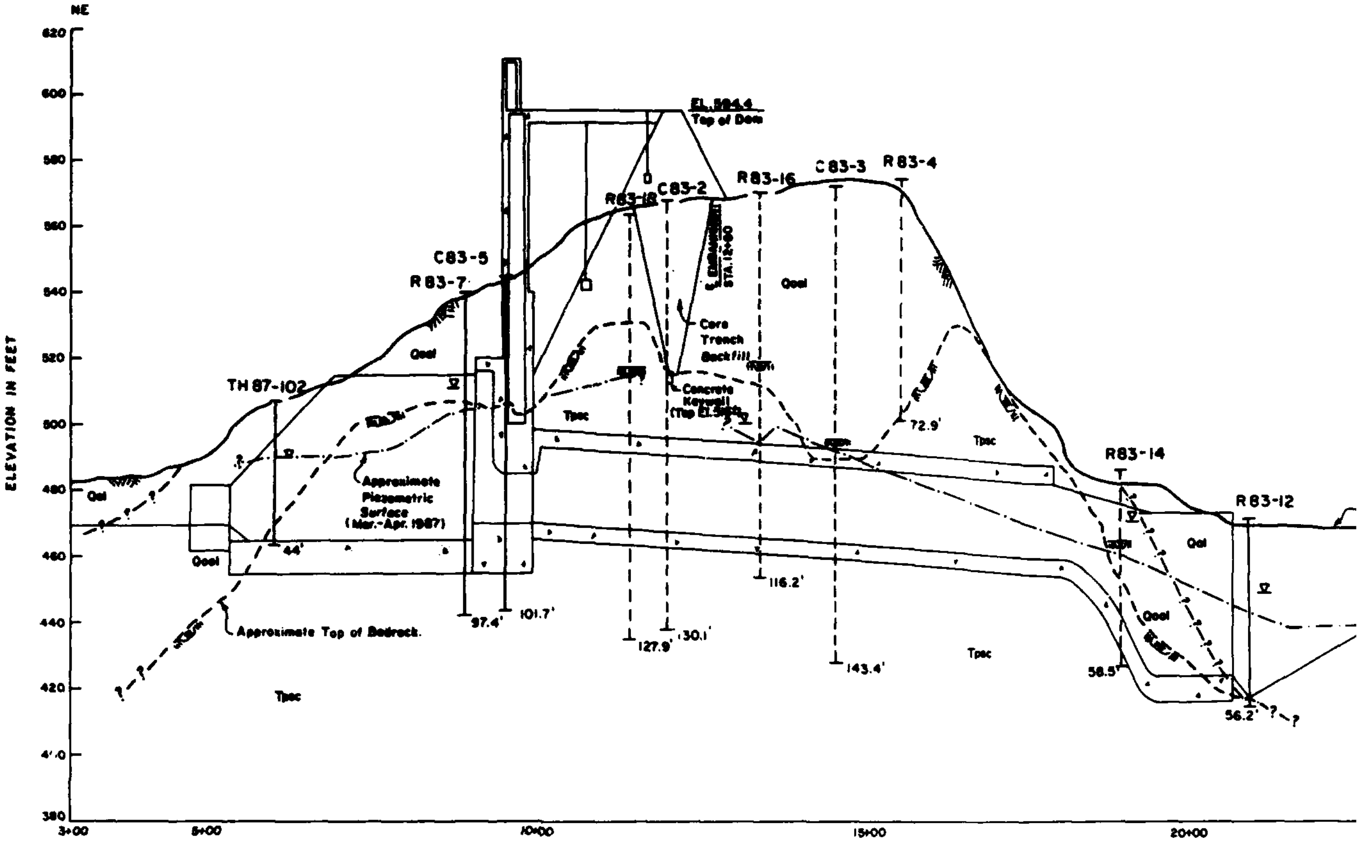
DESIGNED BY:
DRAWN BY: YBA
CHECKED BY:
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-59

SAFETY PAYS

1

2



LEGEND

C83-5
Core boring, giving year drilled and boring number dashed where projected. Depth is in feet.
101.7'

R83-7
Rotary boring, giving year drilled and boring number, dashed where projected. Depth is in feet.
▽ Depth to water during drilling.
97.4'

TH 87-102
Bucket auger test hole, giving year drilled and hole number, dashed where projected. Depth is in feet.
▽ Depth to water during drilling.
44'

Overburden

Bedrock

?- - - Approximate contact between geologic units, queried where conjectural.

?-·- Approximate piezometric surface in March-April 1987, queried where conjectural.

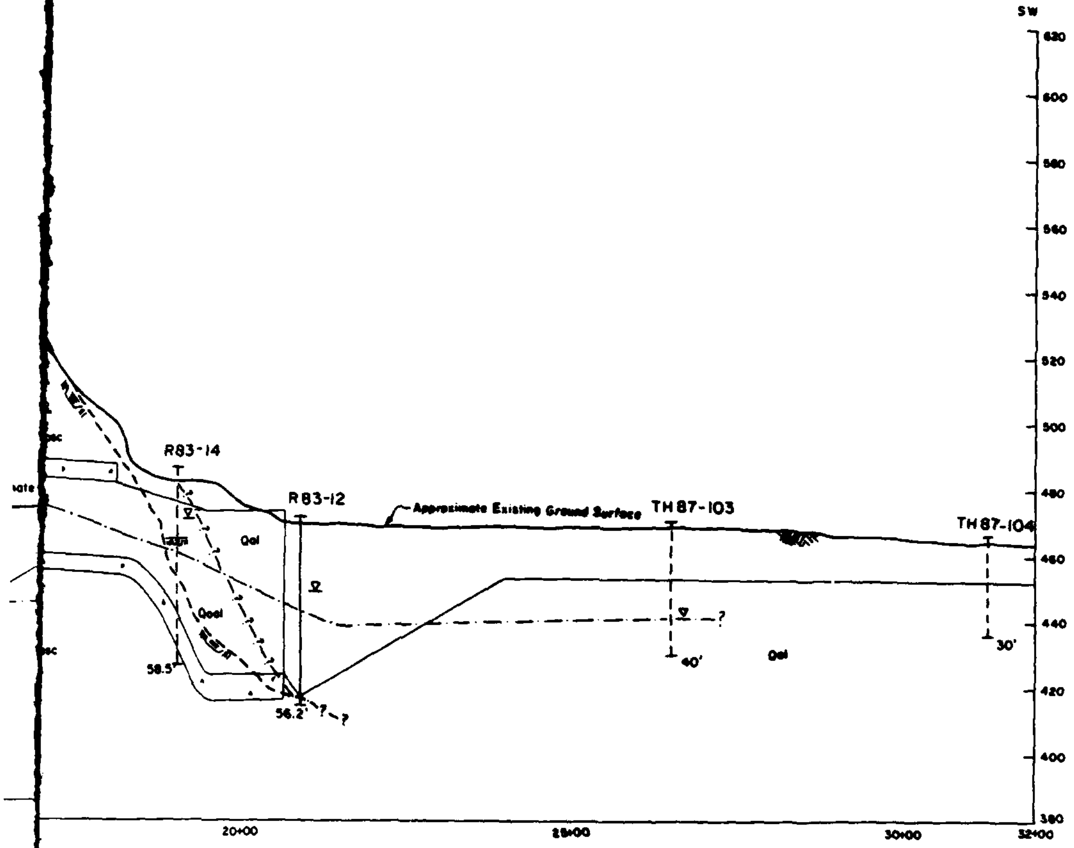
GEOLOGIC PROFILE ALONG ℄ OUTLET WORKS

HORIZ. SCALE 100 0 100 200 300 FEET

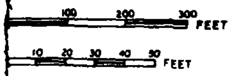
VERT. SCALE 10 0 10 20 30 40 50 FEET

Qal	RECENT ALLUVIUM: Includes lacustrine deposits (Qyl), active stream deposits (Qys), disturbed Quaternary alluvium (dqa) and artificial fill (af).
Qoal	PLEISTOCENE (OLDER) ALLUVIUM: Includes fluvial deposits (Qo_2), a paleosol (So_1, So_2), eolian deposits (Qe), terrace deposits (Qts), disturbed undifferentiated surfaces (dus) and artificial fill (af).
Tpsc	PUENTE FORMATION - SYCAMORE CANYON MEMBER

ALUE ENGINEERING PAYS



FILE ALONG ℄ OUTLET WORKS



lacustrine deposits (Qyl),
, disturbed Quaternary
fill (af).

UM: includes fluvial
So1, So2), eolian
its (Qts), disturbed
s) and artificial

MORE CANYON MEMBER

NOTES:

1. SEE PLATE 52 FOR OUTLET WORKS GEOLOGY AND PLAN OF EXPLORATION.
2. BEDROCK PROFILE DEVELOPED FROM FIELD EXPLORATION DATA AND BEDROCK CONTOUR MAP.
3. PIEZOMETRIC PROFILE DEVELOPED FROM FIELD EXPLORATION DATA AND OBSERVATION WELL MEASUREMENTS TAKEN IN MARCH 1987.
4. SEE PLATES 61 AND 62 FOR OUTLET WORKS GEOLOGIC CROSS SECTIONS.
5. SEE PLATES 53 AND 54 FOR LOGS OF ROTARY BORINGS.
6. SEE PLATE 55 FOR LOGS OF CORE BORINGS.
7. SEE PLATE 56 FOR LOGS OF TEST HOLES.
8. SEE PLATE 59 FOR OUTLET WORKS BEDROCK CONTOUR MAP.
9. SEE PLATE 4 FOR DESCRIPTIONS OF GEOLOGIC UNITS IN LEGEND IDENTIFIED BY WOODWARD-CLYDE CONSULTANTS (1980).

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

OUTLET WORKS

GEOLOGIC PROFILE

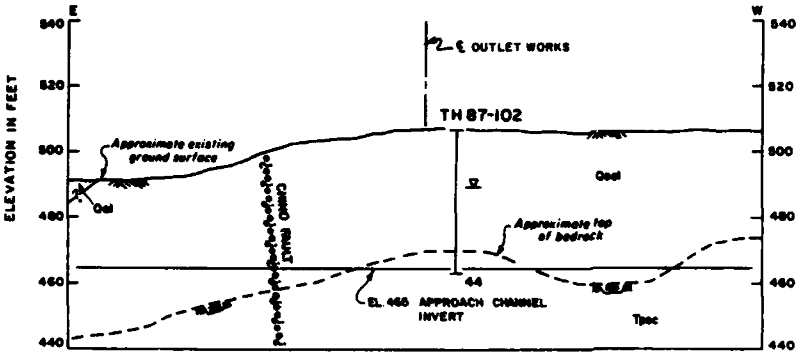
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-60

SAFETY PAYS

2

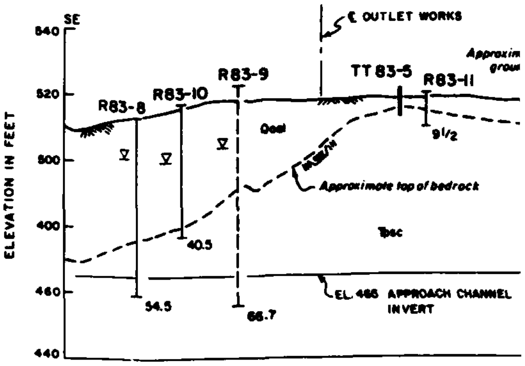
VALUE ENGINEERING I



STATION 6+10

HORIZ. SCALE 50 0 50 100 150 FEET

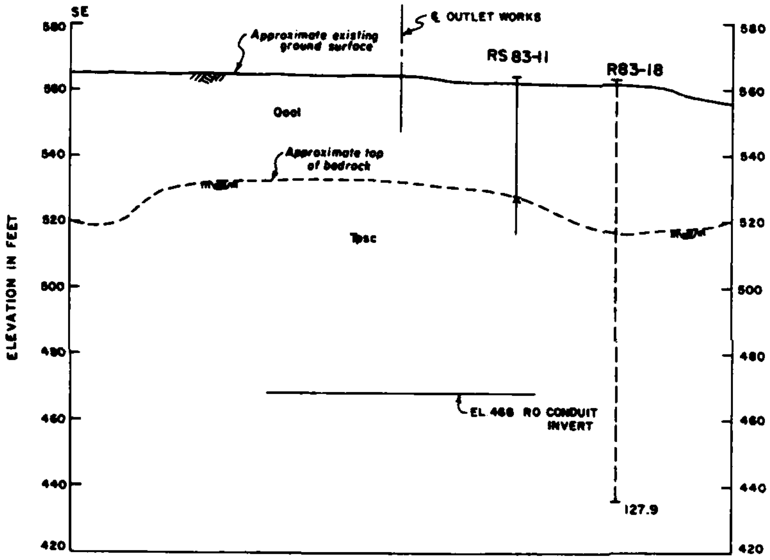
VERT SCALE 10 0 10 20 30 40 50 FEET



STATION 7+50

HORIZ SCALE 50 0 50 100 150 FEET

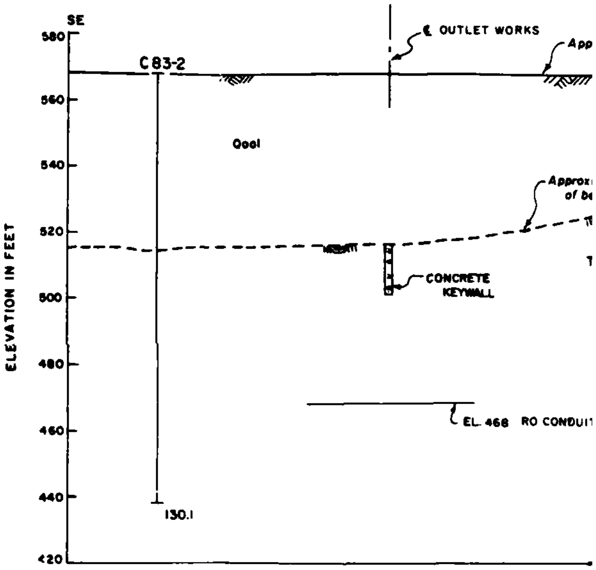
VERT. SCALE 10 0 10 20 30 40 50 FEET



STATION 11+00

HORIZ. SCALE 10 0 10 20 30 40 50 FEET

VERT SCALE 10 0 10 20 30 40 50 FEET



STATION 12+10

HORIZ. SCALE 10 0 10 20 30 40 50 FEET

VERT. SCALE 10 0 10 20 30 40 50 FEET

LEGEND

C 83-5
Core boring, giving year drilled and boring number. Depth is in feet.
101.7

R 83-14
Rotary boring, giving year drilled and boring number, dashed where projected. Depth is in feet.
∇ Depth to water during drilling.
58.5

TH 87-102
Bucket auger test hole, giving year drilled and hole number. Depth is in feet.
∇ Depth to water during drilling.
44

TT 83-5
Test trench, giving year excavated and trench number.

RS 83-4
Seismic refraction survey line, giving year conducted and survey line number. "x" indicates inferred depth to bedrock.

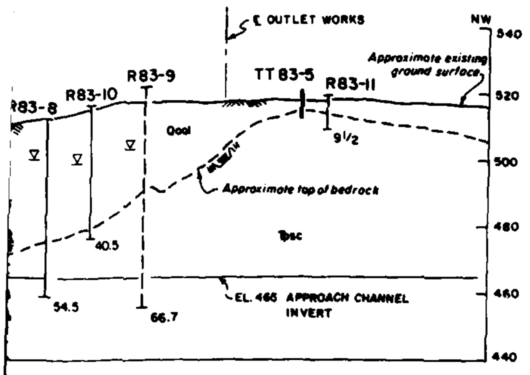
Overburden

Bedrock

Approximate contact between geologic units, queried where conjectural.

Fault, dotted where concealed.

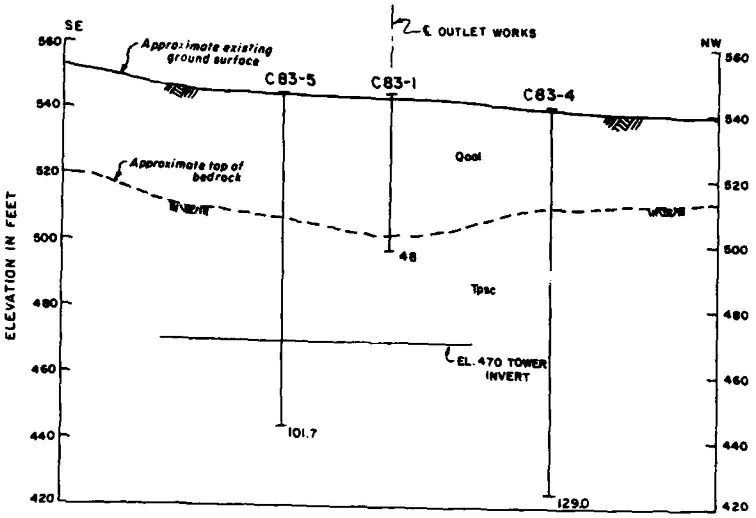
SAFETY PAYS



STATION 7+50

HORIZ SCALE 50 0 50 100 150 FEET

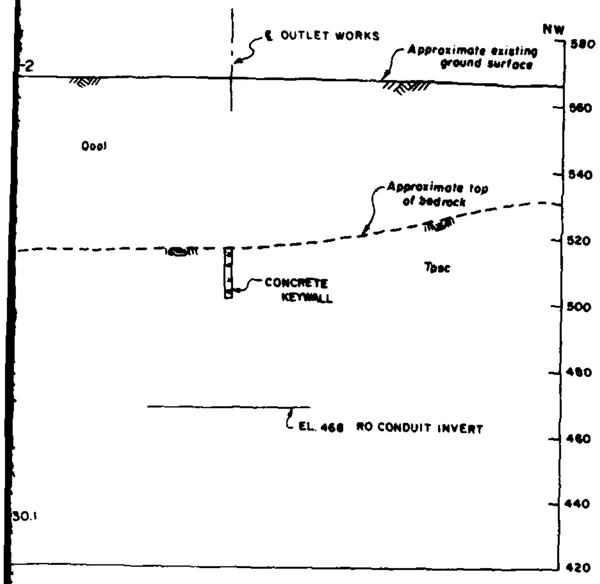
VERT. SCALE 10 0 10 20 30 40 50 FEET



STATION 9+70

HORIZ. SCALE 10 0 10 20 30 40 50 FEET

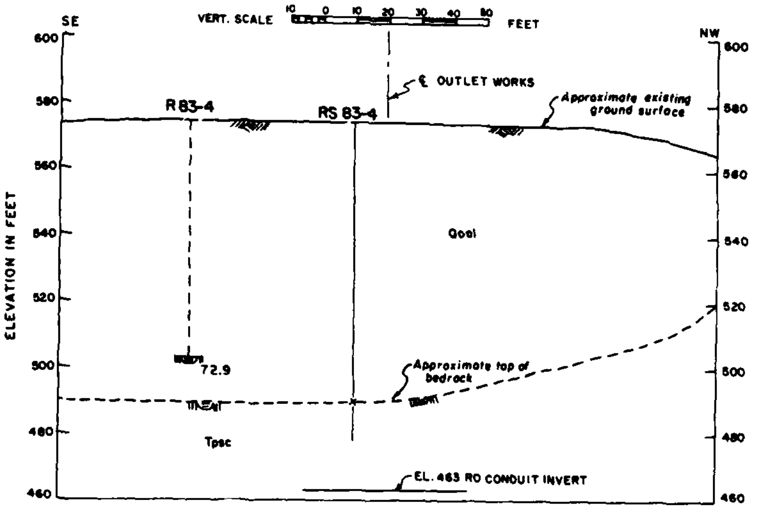
VERT. SCALE 10 0 10 20 30 40 50 FEET



STATION 12+10

HORIZ SCALE 10 0 10 20 30 40 50 FEET

VERT SCALE 10 0 10 20 30 40 50 FEET



STATION 15+00

HORIZ SCALE 10 0 10 20 30 40 50 FEET

VERT. SCALE 10 0 10 20 30 40 50 FEET

NOTES:

1. SEE PLATE 52 FOR OUTLET WORKS GEOLOGY AND PLAN OF EXPLORATION.
2. SEE PLATE 59 FOR OUTLET WORKS BEDROCK CONTOUR MAP.
3. SEE PLATES 53 AND 54 FOR LOGS OF ROTARY BORINGS.
4. SEE PLATE 55 FOR LOGS OF CORE BORINGS.
5. SEE PLATE 58 FOR LOG OF TEST HOLE TH 87-102.
6. SEE PLATE 60 FOR OUTLET WORKS GEOLOGIC PROFILE.
7. SEE PLATE 56 FOR LOG OF TEST TRENCH TT 83-5.
8. SEE PLATE 57 FOR SEISMIC REFRACTION SURVEY VELOCITY PROFILES.
9. TOP OF BEDROCK DEVELOPED FROM FIELD EXPLORATION DATA AND BEDROCK CONTOURS.
10. ALL CROSS SECTIONS DRAWN LOOKING DOWNSTREAM.
11. SEE PLATE 60 FOR DESCRIPTIONS OF GEOLOGIC UNITS.
12. SEE PLATE 52 FOR LOCATION OF STATIONING ALONG OUTLET WORKS CENTER LINE.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

DRAWN BY: YBA

PRADO DAM

OUTLET WORKS

CHECKED BY:

GEOLOGIC CROSS SECTIONS

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

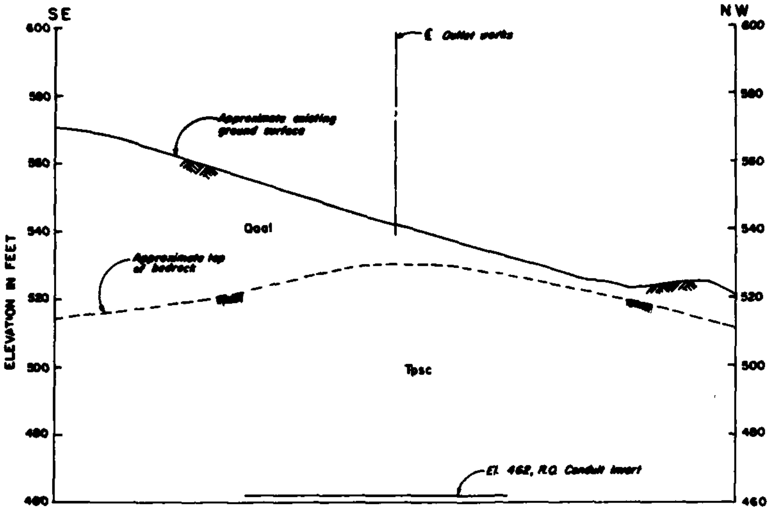
SHEET

DISTRICT FILE NO.

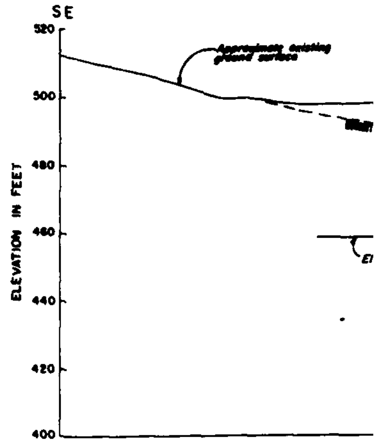
PLATE B-61

1

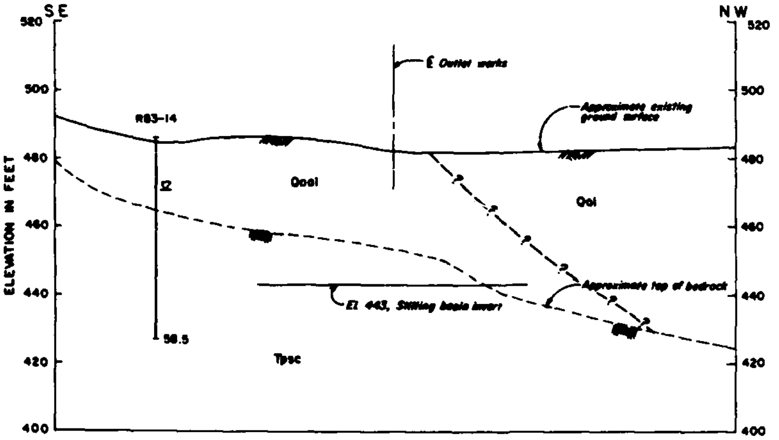
2



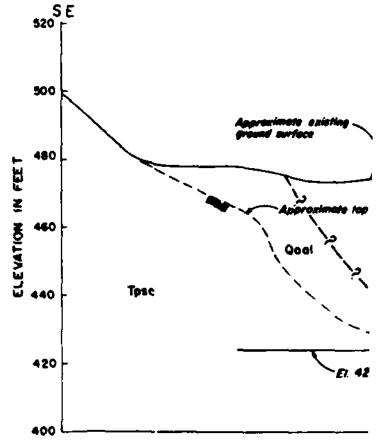
STATION 16+40



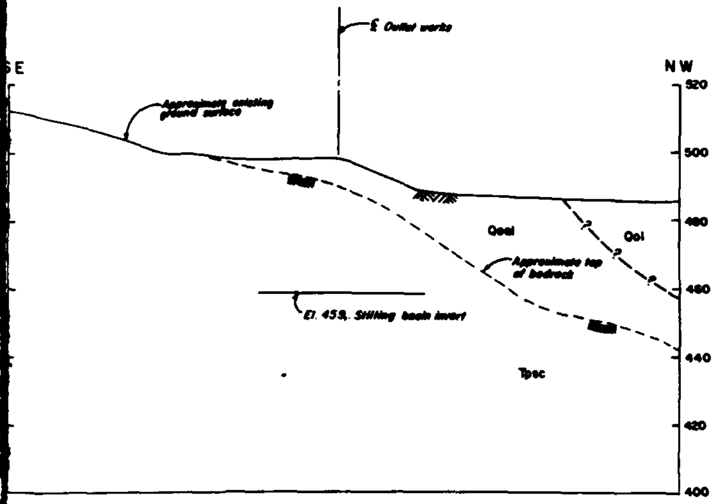
STA



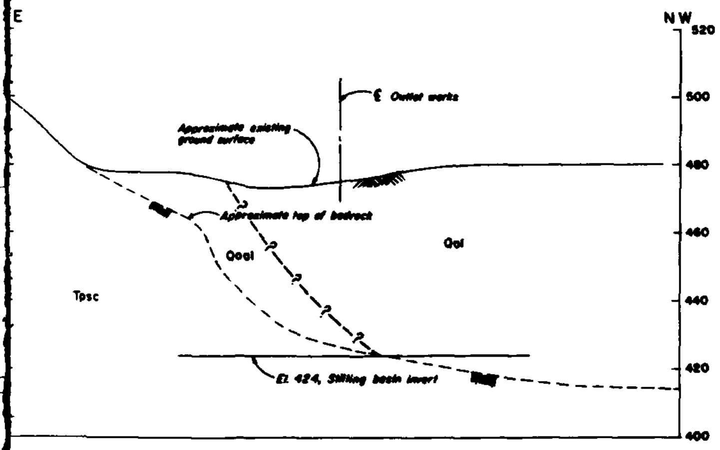
STATION 19+00



ST



STATION 18+00



STATION 20+00

NOTES:

1. SEE PLATE 61 FOR NOTES AND LEGEND

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY: M. O.

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

OUTLET WORKS

GEOLOGIC CROSS SECTIONS

SUBMITTED BY:

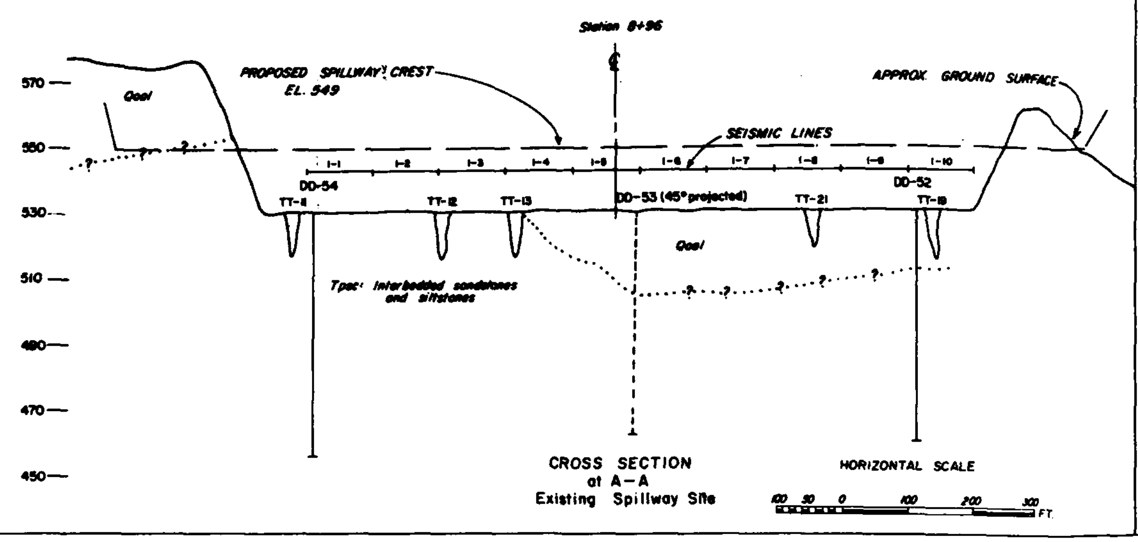
DATE APPROVED:

SPEC. NO. DACW09-____ B-____

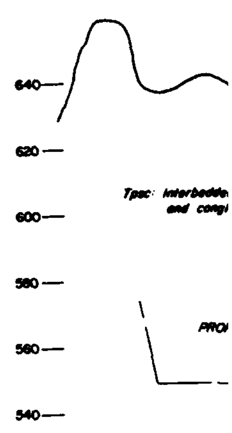
DISTRICT FILE NO.

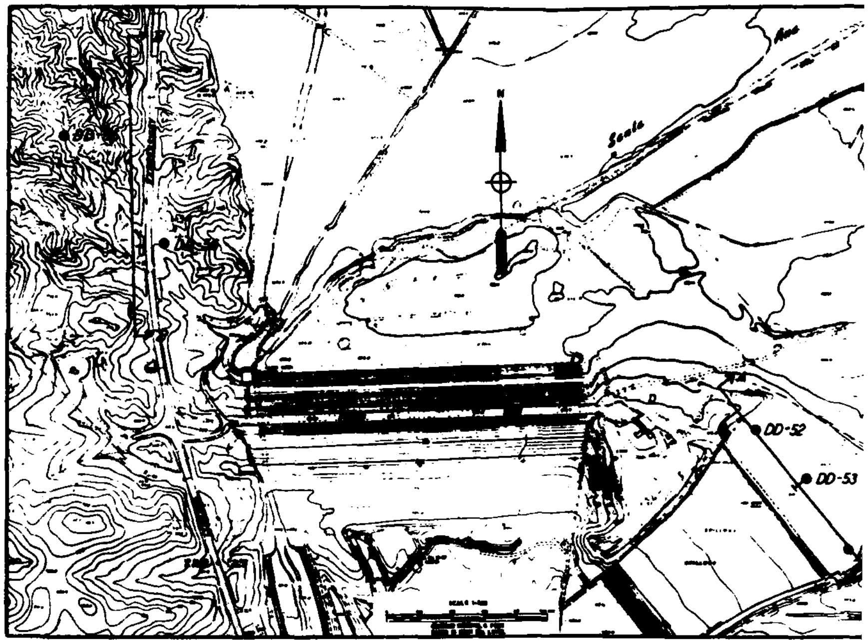
SHEET

PLATE B-62

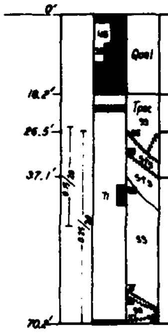


CROSS SECTION
at A–A
Existing Spillway Site





DD-52
El. 530.0



Older Alluvium - Tan to reddish brown sand, gravel and few thin silt lenses. Sand medium to coarse-grained, gravel and cobbles to 12", poorly graded, loose. Silt lenses firm, slightly cohesive, low plasticity.

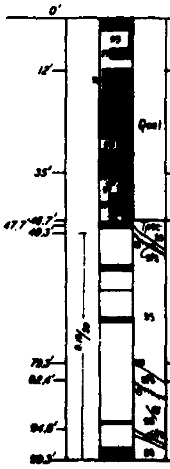
Sandstone - Gray, soft and surface weathered 18.2' to 21.2', Moderately hard below 21.2', loses coherency when wet, fine to medium-grained, micaceous, moderately cemented with clay, few shrinkage cracks.

Siltstone - Tan to brown, sandy, moderately hard to hard, indurated, shrinkage cracks, slakes on exposure to air, slightly porous, scattered small pebbles and 2" to 3" pockets of loose sand 35' to 37', some minute incipient fractures filled with white calcite, bedding dips 85°, several tight shears with slickensides.

Sandstone - Grey to brown, very fine-grained, silty, moderately hard, friable, few pebbles, few tight shears and short parallel joints, slightly porous.

78% bedrock core recovery

DD-53 (inclined)
El. 530.0



Older Alluvium - Silt - Brown, sandy, firm, very low plasticity.

Sand - Tan, medium to coarse-grained, few pebbles, a few streaks of silt, dry, loose.

Sand and gravel - Reddish, 50% pebbles and cobbles to 6" diameter, dry, loose.

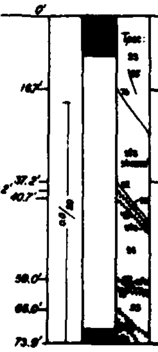
Sandstone - White, soft to moderately soft when wet, more moderately hard when dry, medium to coarse-grained, poorly cemented, friable; pebble sandstone from 76.0' to 79.1' and 91.4' to 93.5' on indistinct 45° angle.

Siltstone - Brown, sandy, clay matrix, moderately hard, tight, sheared along lower contact.

Sandstone - White, moderately soft, medium to coarse-grained, porous.

91% bedrock core recovery

DD-54
El. 529.8



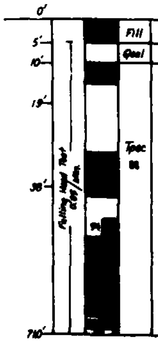
Sandstone - White, soft to moderately soft, surface weathered, very friable, poorly cemented, porous, looses coherency when wet

Siltstone - Brown, moderately hard, sandy, tight, indurated, very slightly porous. Tight shears 0.7' to 3.6' apart, dips mostly 75° with some intersecting 15° and 45° dips, horizontal slickensides.

Sandstone - White, moderately hard, medium to coarse-grained, moderately cemented; brown siltstones with shear contacts; pebble sandstone 61.2' to 66.3', slightly porous. Tight shears 0.1' to 0.3' apart from 45.0' to 61.0', parallel and intersecting 60° to 70° with few 45° dips. Siltstone from 66.3' to 67.3' is totally sheared.

83% bedrock core recovery

DD-56
El. 560.5



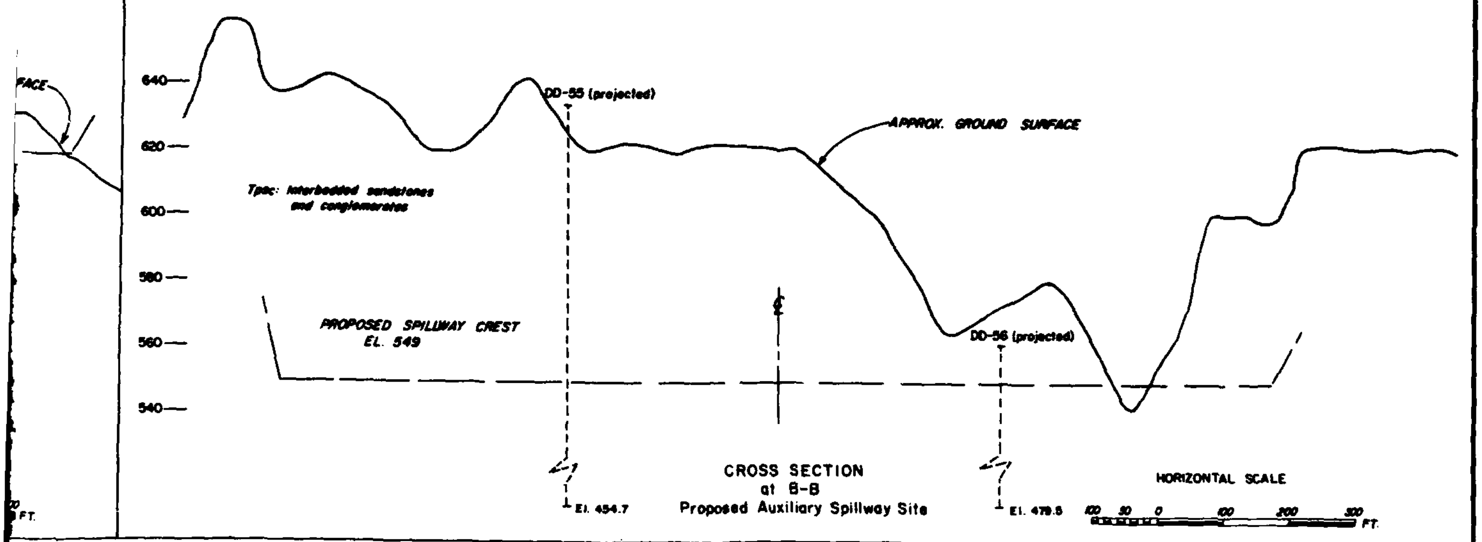
Loose sand, some gravel.

Older Alluvium - Firm, brow

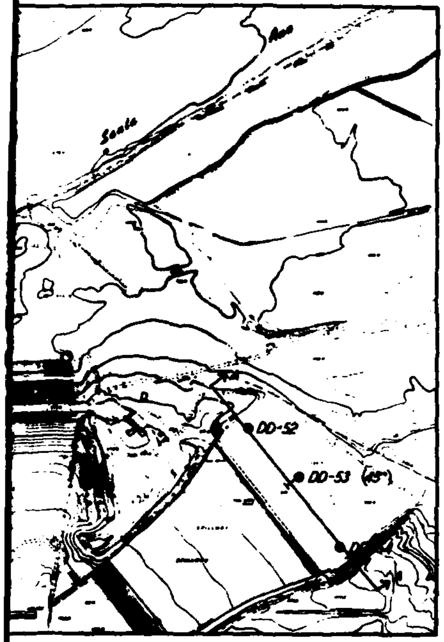
Sandstone - White, soft, me
coarse-grained, very friabl
cemented, porous; pebble sa
from 10' to 19' and 38' to

43% bedrock core recovery

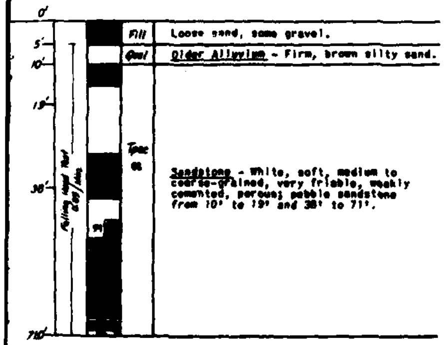
CORPS OF ENGINEERS



CROSS SECTION
at B-B
Proposed Auxiliary Spillway Site



DD-56
El. 560.5



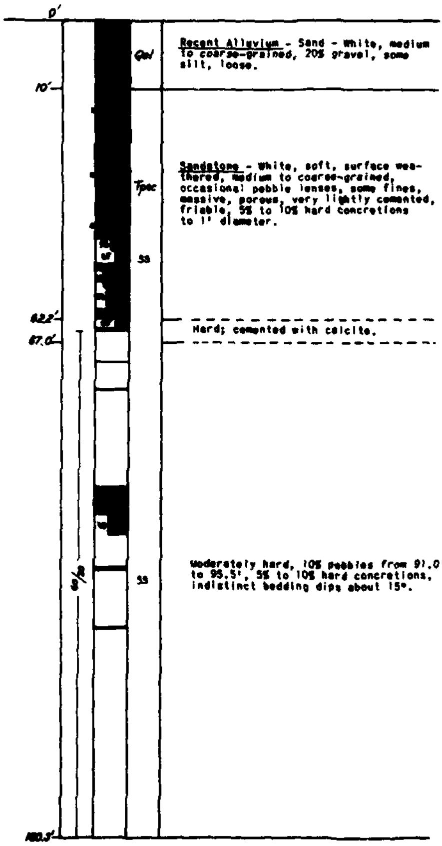
Fill — Loose sand, some gravel.

Qoal — Older Alluvium - Firm, brown silty sand.

Tpsc SS — Sandstone - White, soft, medium to coarse-grained, very friable, weakly cemented, porous; pebble sandstone from 10' to 19' and 38' to 71'.

43% bedrock core recovery

DD-55
El. 635.0



Qal — Recent Alluvium - Sand - White, medium to coarse-grained, 20% gravel, some silt, loose.

Tpsc SS — Sandstone - White, soft, surface weathered, medium to coarse-grained, occasional pebble lenses, some fines, massive, porous, very lightly cemented, friable, 5% to 10% hard concretions to 1' diameter.

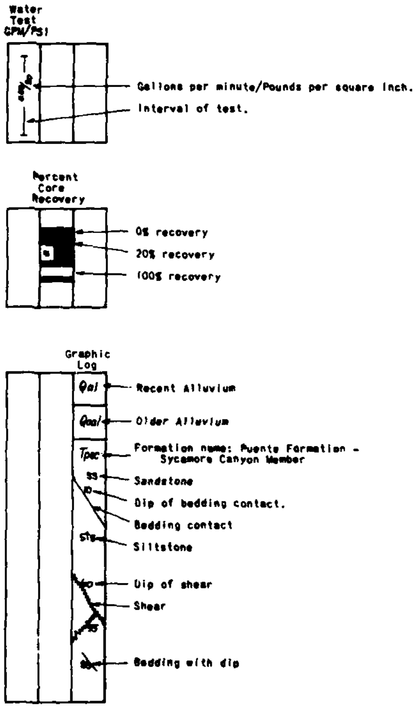
Hard; cemented with calcite.

SS — Moderately hard, 10% pebbles from 91.0' to 95.5', 5% to 10% hard concretions, indistinct bedding dips about 15°.

66% bedrock core recovery

NOTE:
LOCATION AND LOGS OF TEST TRENCHES, AND LOCATION AND PROFILES OF SEISMIC LINES ARE NOT SHOWN.

LEGEND



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

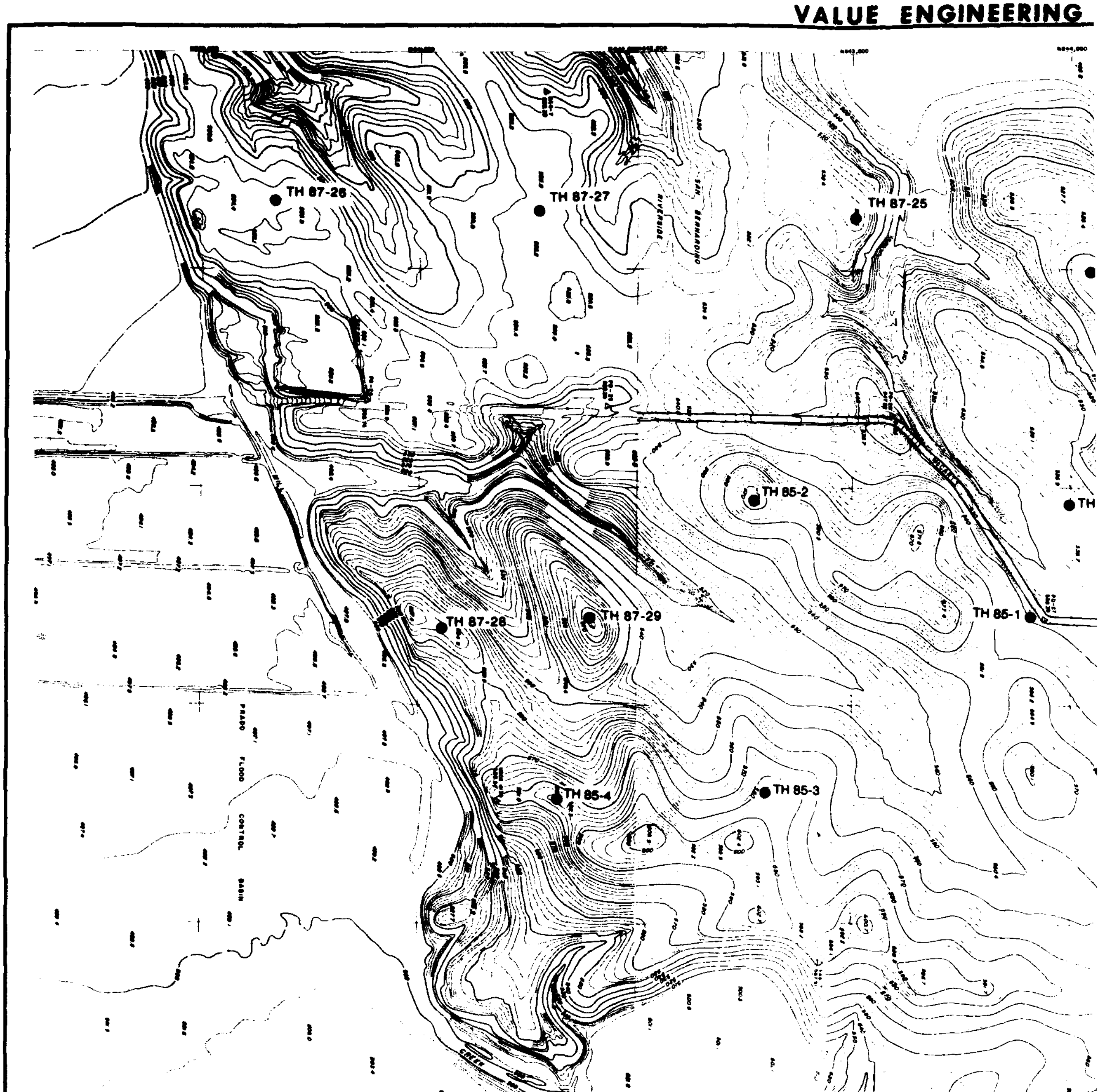
SPILLWAY EXPLORATION
PLAN, SECTIONS AND DRILL LOGS

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

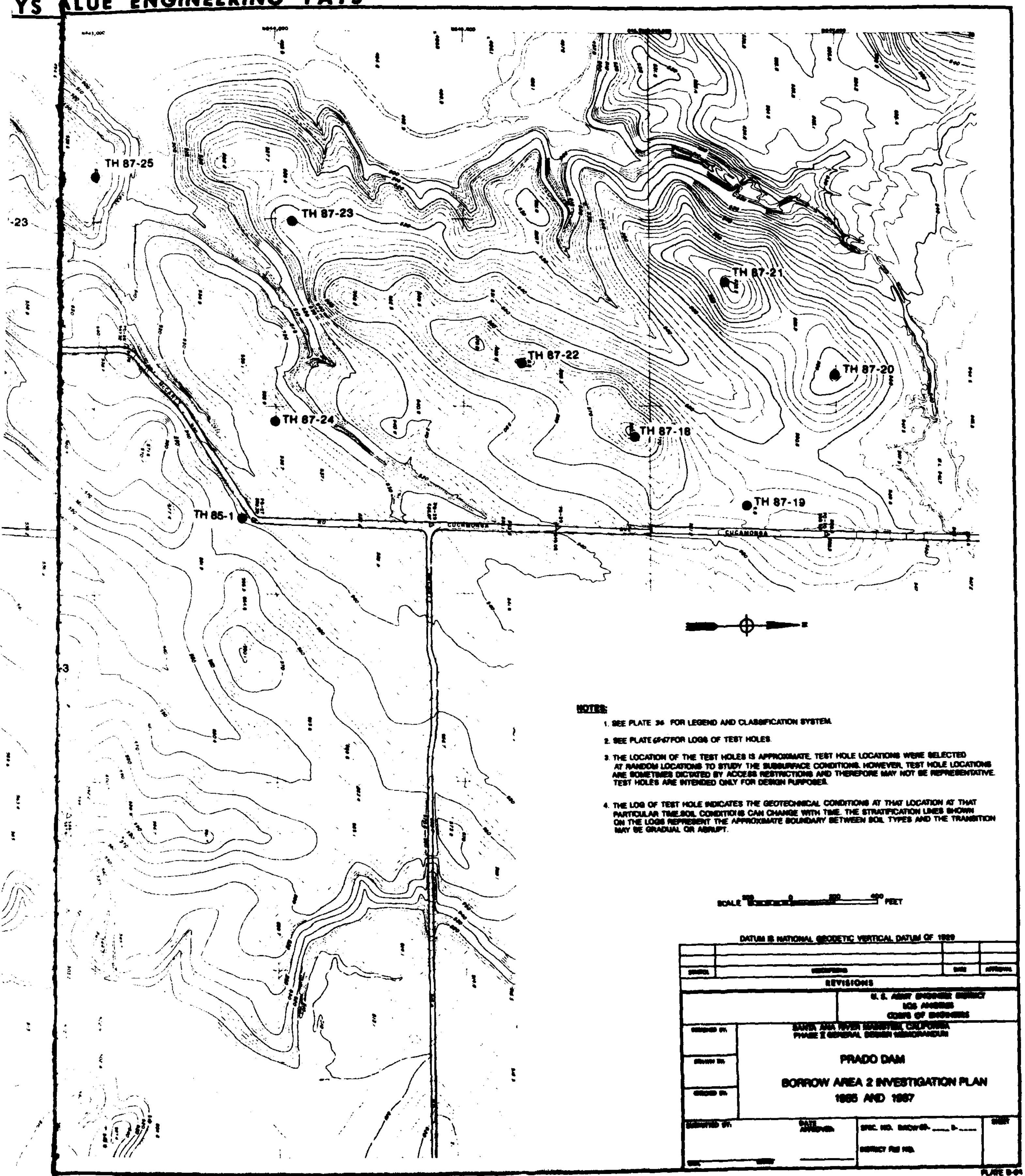
PLATE B-[illegible]

1

2


TH 87-26
TH 87-27
TH 87-25
RIVERSIDE
SAN BERNARDINO
TH 85-2
TH
TH 87-28
TH 87-29
TH 85-1
PRADO FLOOD CONTROL BASIN
TH 85-4
TH 85-3
CREEK
COUNTY
COUNTY

YS ALUE ENGINEERING PAYS



NOTES:

1. SEE PLATE 34 FOR LEGEND AND CLASSIFICATION SYSTEM.
2. SEE PLATE 65-67 FOR LOGS OF TEST HOLES.
3. THE LOCATION OF THE TEST HOLES IS APPROXIMATE. TEST HOLE LOCATIONS WERE SELECTED AT RANDOM LOCATIONS TO STUDY THE SUBSURFACE CONDITIONS. HOWEVER, TEST HOLE LOCATIONS ARE SOMETIMES DICTATED BY ACCESS RESTRICTIONS AND THEREFORE MAY NOT BE REPRESENTATIVE. TEST HOLES ARE INTENDED ONLY FOR DESIGN PURPOSES.
4. THE LOG OF TEST HOLE INDICATES THE GEOTECHNICAL CONDITIONS AT THAT LOCATION AT THAT PARTICULAR TIME. SOIL CONDITIONS CAN CHANGE WITH TIME. THE STRATIFICATION LINES SHOWN ON THE LOGS REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL OR ABRUPT.

SCALE 200 0 200 400 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

BORROW AREA 2 INVESTIGATION PLAN
1985 AND 1987

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET

PLATE B-64

SAFETY PAYS

2

1

TH85-1

DEPTH	LOG	LL	PI	-4	-200	N	DESCRIPTION
3.0'	ML-CL	25	6	90	65		SANDY SILT/SANDY CLAY; dark brown,moist, medium dense.
5.0'	CH	54	35	90	63	36	SANDY CLAY; reddish-brown,moist,very stiff.
6.5'	SM-SC	27	7	97	23	18	SILTY SAND/CLAYEY SAND; reddish,moist,gravels to ½".
9.0'	SW-SM		NP	93	12	25	SILTY SAND; red,moist,medium dense,gravels to 1".
10.0'	CL	30	17	100	93		SANDY CLAY; dark gray with reddish tint,moist, medium dense.
12.0'	ML	30	11	100	77	32	SANDY SILT; moist, medium dense.
	MH	51	22	95	56		SANDY SILT; brown moist,medium dense,occasional cobble to 6".
16.0'		51	20	96	64	33	light brown,dense.
18.0'	SC	38	33	93	43		CLAYEY SAND; reddish-brown to light tan,medium dense,gravels to 1".
	SM	43	15	86	31		SILTY SAND; reddish brown to light tan,medium dense,occasional cobble to 6".
		46	16	81	22		GRAVELLY SILTY SAND; light tan,moist,dense, gravels to 1½".
24.0'		40	12	65	18		SILTY GRAVELLY SAND; light tan,moist gravels to 1½" occasional cobble to 8".

TH85-2

DEPTH	LOG	LL	PI	-4	-200	N	DESCRIPTION
1.0'	SC	32	13	90	34		CLAYEY SAND; brown,dry,dense,gravels to 1.5".
2.5'	SM		NP	97	25	36	SILTY SAND; reddish-brown,moist,very dense.
4.0'	SC	30	14	75	18		CLAYEY GRAVELLY SAND; reddish-brown,moist, gravels to 1".
6.0'	SW-SM		NP	65	10		SILTY GRAVELLY SAND; reddish-brown,moist, gravels to1.5".
8.0'	SC	34	15	70	14		CLAYEY GRAVELLY SAND; reddish brown,moist, gravels to 2".
10.0'	SM		NP	64	13		SILTY GRAVELLY SAND; light tan,moist,dense, gravels to 1 .
13.0'	SW-SM		NP	62	9		GRAVELLY SAND; light tan,moist,dense,gravels to 2",cobbles to 5".
16.5'	SM		NP	69	14		SILTY GRAVELLY SAND; brown,moist,dense,gravels to 2".
19.0'	SP-SM		NP	68	8		GRAVELLY SAND; brown,moist,dense,gravels to 3".
22.5'	ML	46	11	99	52		SANDY SILT; light tan,moist.
24.5'	SM	31	7	64	32		GRAVELLY SILTY SAND; reddish-brown,gravels to 1"
27.0'	GP-GM		NP	49	12		SILTY SANDY GRAVEL; dark brown,moist.
	SW-SM		NP	70	12		SILTY GRAVELLY SAND; light brown,moist,gravels to 2".
33.0'			NP	63	11		
	SC	32	9	94	18		CLAYEY SAND; reddish-tan,moist,dense,occasional cobble to 10".
38.0'		31	9	70	19		CLAYEY GRAVELLY SAND; brown,moist,dense,gravels to 3".

TH 85-3

DEPTH	LOG	LL	PI	-4	-200	DESCRIPTION
	SC	33	15	72	36	GRAVELLY CLAYEY SAND; dark brown,slightly moist,occasional cobble to 10".
		37	14	77	30	light brown,gravels to 3".
9.0'		30	17	62	18	CLAYEY GRAVELLY SAND; moist.
12.0'	SP-SM		NP	61	10	GRAVELLY SAND; light brown,moist,occasional cobbles to 4".
15.0'	SC	45	23	62	13	CLAYEY GRAVELLY SAND; dark brown,moist,dense, gravels to 1½".
18.0'	GP-GM		NP	51	8	SANDY GRAVEL; dark brown,moist,dense,gravels to 3".
	SP-SM		NP	61	10	GRAVELLY SAND; dark brown,moist,cobbles to 5".
25.0'			NP	67	10	gravels to 1.5".
26.0'	SP-SM		NP	75	10	light tan,moist,medium dense.
28.0'	SC	28	15	98	16	CLAYEY SAND; dark brown,moist,dense,gravel to 2"
30.0'	SP-SM		NP	84	7	GRAVELLY SAND; brown,moist,gravels to 1.5".
35.0'	SC	30	21	64	15	CLAYEY GRAVELLY SAND; brown,moist.
38.0'	GW-GM		NP	34	11	SILTY SANDY GRAVEL; dark brown,moist,medium dense,occasional 6" cobble.
40.0'	SP-SM		NP	86	8	GRAVELLY SAND; light brown,moist,dense,gravels to 1.5".
45.5'	GP-GM		NP	34	10	SANDY GRAVEL; brown,moist,dense,gravels to 3".
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SILTY GRAVELLY SAND; brown,moist,dense cobbles to 6".
48.0'	GP-GM		NP	40	9	SANDY GRAVEL/SILTY SANDY GRAVEL; light brown, moist,dense gravels to 4".
50.0'	MH	52	20	98	92	SANDY SILT; reddish-brown medium dense,gravels to 3".
53.0'	CL	45	21	100	96	SANDY CLAY; light tan,moist,stiff some gravels to 1".
57.0'	SC	35	15	90	30	CLAYEY SAND; light brown,moist,gravels to 2", occasional cobble to 8".
58.0'	SM	[illegible]	[illegible]	75	[illegible]	SILTY GRAVELLY SAND; light brown,moist,gravels to 2",occasional cobble to 8".

TH85-4

DEPTH	LOG	LL	PI	-4	-200	N	DESCRIPTION
	SC	34	16	82	29	30	GRAVELLY CLAYEY SAND; dark brown,dry,dense.
		31	18	88	23		reddish brown,moist,gravels to 2".
7.0'		46	20	77	15		CLAYEY GRAVELLY SAND; reddish,moist,medium to very dense,gravels to 3",occasional cobble.
9.5'	GP-GM		NP	51	7		SANDY GRAVEL; light brown,moist,dense gravel to 3",occasional cobble.
12.0'	SP-SM		NP	59	10		GRAVELLY SAND; dark brown,moist.
	SC	30	16	86	32	80+	CLAYEY SAND; reddish-light tan,moist,very dense.
17.0'		42	18	76	14		CLAYEY GRAVELLY SAND; reddish-brown,moist,dense, gravels to 3".
18.5'	SM	51	22	78	36		GRAVELLY SILTY SAND; reddish brown to light tan, medium dense,gravels to 2".
	SW-SM		NP	71	12		SILTY GRAVELLY SAND; light tan,moist,medium dense, gravels to 1",occasional cobble to 5".
			NP	73	11		gravels to 1.5"
31.0'			NP	67	11		reddish-brown,gravels to 3"
	SM	48	14	86	29		SILTY SAND; tan,moist,medium dense,gravels to 1½".
		57	18	100	43		light brown,medium dense.
		46	14	99	40		reddish brown,moist.
		48	16	99	40		light brown,gravels to 1".
46.0'		36	9	78	21		SILTY GRAVELLY SAND; brown,moist,dense,gravels to 1.5".
	SP-SM		NP	84	10		GRAVELLY SAND; light brown,moist,dense,gravels 1.5",occasional cobble to 6".
58.0'			NP	61	10		no cobbles

DESCRIPTION

YEY SAND; brown,dry,dense,gravels to 1.5".
Y SAND; reddish-brown,moist,very dense.
YEY GRAVELLY SAND; reddish-brown,moist.
els to 1".
Y GRAVELLY SAND; reddish-brown,moist,
els to1.5".
YEY GRAVELLY SAND; reddish brown,moist,
els to 2".
Y GRAVELLY SAND; light tan,moist,dense,
els to 1 .
ELLY SAND; light tan,moist,dense,gravels
",cobbles to 5".
Y GRAVELLY SAND; brown,moist,dense,gravels
".

ELLY SAND; brown,moist,dense,gravels to 5".

Y SILT; light tan,moist.

ELLY SILTY SAND; reddish-brown,gravels to 1"

Y SANDY GRAVEL; dark brown,moist.

TY GRAVELLY SAND; light brown,moist,gravels
".

YEY SAND; reddish-tan,moist,dense,occasional
ble to 10".
YEY GRAVELLY SAND; brown,moist,dense,gravels
3".

-4

DESCRIPTION

VELLY CLAYEY SAND; dark brown,dry,dense.

ddish brown,moist,gravels to 2".
YEY GRAVELLY SAND; reddish,moist,medium
very dense,gravels to 3",occasional cobble.
DY GRAVEL; light brown,moist,dense gravel to
,occasional cobble.
VELLY SAND; dark brown,moist.

YEY SAND; reddish-light tan,moist,very dense.

YEY GRAVELLY SAND; reddish-brown,moist,dense,
avels to 3".
VELLY SILTY SAND; reddish brown to light tan,
dium dense,gravels to 2".
LTY GRAVELLY SAND; light tan,moist,medium dense,
avels to 1",occasional cobble to 5".

avels to 1.5"

ddish-brown,gravels to 3"

ILTY SAND; tan,moist,medium dense,gravels to 1½".

ght brown,medium dense.

ddish brown,moist.

ght brown,gravels to 1".

LTY GRAVELLY SAND; brown,moist,dense,gravels
1.5".

VELLY SAND; light brown,moist,dense,gravels
5",occasional cobble to 6".

cobbles

NOTES:

1. SEE PLATE #9 FOR LOCATION OF BORROW AREAS.
2. SEE PLATE 36 FOR LEGEND AND CLASSIFICATION SYSTEM.

SCALE 0 5 10 15 20 FEET

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
SOIL LOGS
BORROW AREA NO. 2
1985

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____B-____
DISTRICT FILE NO.
SHEET

PLATE B-66

1

2

TH 87-18

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SC		38	21	84	36		GRAVELLY,CLAYEY SAND; dark brown,dry.
			54	35	80	25		SAME.
		13	39	20	97	46	47	CLAYEY SAND; light brown,moist,dense.
			33	13	100	40	45	SAME; very dense,large clumps.
10.5'		7	34	17	90	17		SAME; gravels to 2".
	SP-SC		42	25	73	9		GRAVELLY SAND/CLAYEY SAND; light brown, moist,gravels to 2".
20.0'		8	44	27	63	12		SAME; slightly cohesive,cobbles to 8".
21.0'	CH		56	37	100	77		SANDY CLAY; grey,moist,cohesive.
23.0'	SC		53	36	72	14		GRAVELLY CLAYEY SAND; light brown,moist, slightly cohesive,gravels to 3".
25.0'	SP-SC		46	29	71	11		GRAVELLY SAND/CLAYEY SAND; light brown, moist.
	SC							GRAVELLY CLAYEY SAND; light brown,moist, cobbles to 8".
		9	43	24	61	18		SAME; slightly cohesive.
								SAME; 12" cobble in bucket.
39.0'			51	34	72	13		SAME; brown,cobbles to 11".

NOTE: STOPPED DUE TO DIFFICULT DIGGING.

TH 87-19

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
2.0'	CL	11	43	27	87	53		SANDY CLAY, dark brown,moist,cohesive, some cobbles.
	SC		54	35	64	18		CLAYEY, GRAVELLY SAND.
		14	32	14	90	37		CLAYEY SAND; light brown,moist,loose.
		14	40	23	75	15		CLAYEY,GRAVELLY SAND; light brown, moist,gravel to 3".
14.5'			48	30	76	15		SAME
16.5'	CL	26	48	30	100	68		SANDY CLAY; light brown,moist.
19.0'	CH		57	33	96	57		SAME; grey brown,cobbles.
	SC	16	48	25	78	21		CLAYEY,GRAVELLY SAND; light brown, moist,cobbles.
			45	24	93	40		CLAYEY SAND; brown,moist,cobbles.
			50	28	78	22		CLAYEY GRAVELLY SAND; grey brown,moist, cobbles to 6".
								SAME
38.5'			43	21	73	23		SAME; grey.
41.0'								SAME

TH 87-21

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
2.0'	CL		33	15	90	53		SANDY CLAY; dark brown,dry,hard,thin layer of cemented material,gravel to 3".
	SC	10	44	25	74	20		GRAVELLY CLAYEY SAND; light brown,dry, loose,3" cobbles,12" cobble in bucket.
6.0'		11	47	30	67	22		SAME ; moist.
12.0'	SP-SC		61	38	66	12		GRAVELLY SAND/CLAYEY SAND; light brown, moist,cobbles to 6".
	SC	11	46	29	62	16		CLAYEY,GRAVELLY SAND; light brown,moist, cobbles to 6".
18.0'			47	29	60	15		SAME.
21.0'	SW-SC		52	34	60	9		GRAVELLY SAND/CLAYEY SAND; light brown, moist,cobbles to 6".
	SC		53	33	69	16		CLAYEY,GRAVELLY SAND; light brown,moist, cobbles to 6".
		13	54	34	73	22		SAME
		15	54	34	72	21		SAME
								SAME
		15	59	40	60	16		SAME
			56	37	68	21		SAME; some cohesion.
42.0'								SAME; cobbles to 8".
44.0'	CH		79	54	86	48		SANDY CLAY; green,moist,cohesive.
46.5'	CH		84	58	100	82		SAME; grey to brown,stiff.
	SW-SC	15	75	55	71	11		GRAVELLY SAND/CLAYEY SAND; grey,moist, gravel to 3".
49.0'								SAME; cobbles to 10".

TH 87-22

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
	SC		44	24	78	19		GRAVELLY,CLAYEY SAND; dark brown, dry.
6.0'		10	46	28	74	14		SAME; light brown,moist,slightly cohesive,gravel to 3".
	SW-SC	9	49	33	60	11		GRAVELLY SAND/CLAYEY SAND: light brown, moist,slightly cohesive,cobbles to 6".
14.0'			49	31	60	10		SAME; cobbles to 8".
17.0'	SC		43	26	61	14		GRAVELLY,CLAYEY SAND: light brown,moist, slightly cohesive,cobbles to 8",15" boulder in bucket.
	SW-SC	10	45	27	72	12		GRAVELLY SAND/CLAYEY SAND; light brown, moist,slightly cohesive ,cobbles to 8".
28.0'			46	27	61	9		SAME; cobbles to 6".
	SC	11	47	28	84	13		CLAYEY,GRAVELLY SAND: light brown,moist.
			47	28	74	13		SAME; light red brown,cobbles to 4".
35.0'								SAME: cobbles to 6".
42.0'	SP-SC		46	30	71	9		GRAVELLY SAND/CLAYEY SAND: light red brown, moist,cobbles to 6".
	SW-SC		53	36	70	9		SAME; slightly cohesive.
50.0'								SAME

NOTE: MOVED HOLE 5 FEET DUE TO LARGE BOULDER AT 7-FOOT DEPTH.

VALUE ENGINEERING PAYS

PA

19

DESCRIPTION

	MC	DESCRIPTION
		Y. CLAY; dark brown,moist,cohesive, e cobbles.
		YEY, GRAVELLY SAND
		YEY SAND; light brown,moist,loose.
	10	
		YEY,GRAVELLY SAND; light brown, ist,gravel to 3".
	11	
		E
SC	8	Y CLAY; light brown,moist.
		E; grey brown,cobbles.
C		
		YEY,GRAVELLY SAND; light brown, st,cobbles.
		YEY SAND; brown,moist,cobbles.
SC		
		YEY GRAVELLY SAND; grey brown,moist, bles to 6".
C		E
		; grey.
SC		
C	16 15	

22

DESCRIPTION

LOG	MC	L	DESCRIPTION
			ELLY,CLAYEY SAND; dark brown.
L		3	; light brown,moist,slightly sive,gravel to 3".
GM	3		ELLY SAND/CLAYEY SAND: light brown, ,slightly cohesive,cobbles to 6".
L	17	2	cobbles to 8".
	22	59	ELLY,CLAYEY SAND: light brown,moist, tly cohesive,cobbles to 8",15" der in bucket.
H	22	50	LLY SAND/CLAYEY SAND; light brown, ,slightly cohesive,cobbles to 8".
		46	cobbles to 6".
		45	
L		44	
			Y, GRAVELLY SAND: light brown,moist.
C	9	39	light red brown,cobbles to 4",
		46	cobbles to 6".
		22	LLY SAND/CLAYEY SAND: light red brown, ,cobbles to 6".
C	13	32	
L	18	37	slightly cohesive.
C		45	

MOVED HOLE 5 FEET DUE TO LARGE BOULDER AT 7-FOOT DEPTH.

TH 87-20

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
1.0'	CL		32	17	94	69		SANDY CLAY; dark brown,moist.
2.0'	CH		53	36	97	64		SAME
	SC	10	48	28	69	21		CLAYEY,GRAVELLEY SAND; reddish brown, dry,very dense,cobbles to 8".
								SAME; moist.
11.0'		11	35	15	79	20		SAME; light brown,gravel to 3".
14.0'	SW-SC	8	43	25	63	12		GRAVELLY,SAND/CLAYEY SAND; light brown, moist,12" cobbles.
	SC		44	26	59	13		CLAYEY GRAVELLY SAND; light brown,moist, boulders.
18.0'			46	28	58	13		SAME; 12" cobbles.
	SW-SC		52	33	58	11		GRAVELLY SAND/CLAYEY SAND; light brown, moist,cobbles to 6".
23.5'								SAME; SPT attempted,20+ blows in the seating layer.
	SC		43	23	66	21		CLAYEY GRAVELLY SAND; light brown,moist, clumps of clay,driller estimated cobbles to 8".
30.0'								SAME; fewer clumps of clay.
	SP-SC		42	20	59	11		GRAVELLY SAND/CLAYEY SAND; light brown,moist, cobbles to 8".
			50	32	74	10		SAME; cobbles to 6".
			49	30	60	12		SAME
38.0'			57	39	72	10		SAME; cobbles to 4".
	SC							GRAVELLY CLAYEY SAND;
		16	69	48	81	23		SAME; red brown,wet.
		15						SAME; grey brown.
42.0'			65	44	78	25		SAME; light brown,clumps of clay,cobbles to 4".

NOTE: STOPPED DUE TO LARGE BOULDER.

TH 87-23

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	CL		38	23	100	52		SANDY CLAY; dark brown,moist,cohesive.
8.0'	SW-SM	3		NP	98	11	50R	SAND/SILTY SAND; brown,moist,loose.
12.0'	CL	17	27	9	100	53		SANDY CLAY; grey to brown,moist,cohesive.
	CH	22	59	34	100	95	58	CLAY; grey,moist,very cohesive.
17.0'		22	50	31	100	90	57	SAME
	CL		48	30	100	83		SANDY CLAY; grey,moist,very cohesive.
			46	27	100	81		SAME
27.5'			44	27	100	80		SAME
30.0'	SC	9	39	25	92	23		CLAYEY SAND; brown,moist,cohesive.
32.0'	CL		46	31	98	70		SANDY CLAY; grey to brown,moist,very cohesive.
	SC		22	2	91	30		CLAYEY SAND; grey,moist,loose.
		13	32	17	99	46		SAME; brown,cohesive
39.0'								SAME; red brown.
45.0'	CL	18	37	20	99	59		SANDY CLAY; red brown,moist,cohesive.
▽ 49.0'	SC		46	28	92	37		CLAYEY SAND; grey to brown,moist,cohesive.

NOTES:

1. SEE PLATE 44 FOR LOCATION OF TEST HOLES.
2. SEE PLATE 36 FOR LEGEND AND CLASSIFICATION SYSTEM.
3. TEST HOLES WERE DRILLED USING A 24"BUCKET AUGER IN APRIL 1987.
4. THE DEPTH TO GROUNDWATER IS APPROXIMATE AND IS EXPECTED TO VARY SEASONALLY AND FROM YEAR TO YEAR.
5. THE LOG OF THAT HOLE INDICATES THE GEOTECHNICAL CONDITIONS AT THAT LOCATION AT THAT PARTICULAR TIME. SOIL CONDITIONS CAN CHANGE WITH TIME THE STRATIFICATION LINES SHOWN ON THE LOGS REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL OR ABRUPT.

VERTICAL SCALE: 1 INCH = 5 FEET

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY: LBa

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
SOIL LOGS
BORROW AREA NO.2
TH 87-18 THROUGH TH 87-23

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

PLATE B-66

SAFETY PAYS

2

VALUE ENGINEERIN

TH87 - 24

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	CL		29	12	97	52		SANDY CLAY; brown, moist.
	SM		24	3	100	47		SILTY SAND; light brown, dry, loose.
10.0'		6	24	3	100	33		SAME
	SM-SC		26	6	97	34		SILTY SAND/CLAYEY SAND; light brown, moist, cohesive.
16.0'			23	5	96	47		SAME
18.5'	SM			NP	100	20		SILTY SAND; light brown, moist, loose, cohesionless.
21.0'	CH	29	74	51	100	97		CLAY; grey, moist, cohesive.
23.0'	CL		44	25	100	81		SANDY CLAY; grey, moist, cohesive.
26.0'	SC	22	33	19	96	41		CLAYEY SAND; grey, moist, cohesive.
	CH		53	34	99	90		CLAY; grey, moist, cohesive.
33.0'								SAME; few gravels.
	CL		36	21	97	69		SANDY CLAY; brown, moist, cohesive.
40.0'								SAME; grey.
	CL		37	22	99	54		SAME
▽ 50.0'			29	13	96	50		SAME; wet.

TH87 - 25

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
3.0'	SM			NP	98	40		SILTY SAND; brown, dry, loose.
	SC		25	11	94	37		CLAYEY SAND; dark brown, dry, loose.
9.0'		3						SAME; damp, slightly cohesive.
13.5'	SP-SM			NP	90	7		SAND/SILTY SAND; brown, moist, loose.
15.0'	CL		44	24	100	81		SANDY CLAY; grey, moist, very cohesive.
18.0'	SM			NP	100	31		SILTY SAND; light brown, moist, loose.
	SC		26	9	100	29		CLAYEY SAND; grey, moist, loose, thin layers of clay.
28.0'			32	16	100	49		SAME: cohesive.
	CL		37	18	100	70		SANDY CLAY; grey, moist, cohesive, thin layers of clay.
			36	18	100	67		SAME
35.0'								SAME
37.0'	SC		29	11	98	38		CLAYEY SAND; grey to brown, moist, loose, few gravels.
38.0'	SP-SM			NP	72	5		SAND/SILTY SAND; grey, moist.
41.0'	SC		28	9	85	29		GRAVELLY, CLAYEY SAND; grey to brown, moist, loose.
44.0'		14						SAME

NOTE: Stoped due to layer of cobbles and boulders.

DEPTH	LOG
2.0'	SM
5.0'	SC
7.0'	SM-SC
10.0'	SC
13.0'	SM-SC
15.0'	CL
19.0'	CH
24.0'	CL
29.0'	CH
35.0'	CH
38.0'	SC
42.0'	CH
▽ 44.0'	
47.0'	

TH87-27

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
5.0'	SC	10	41	26	100	27		CLAYEY SAND; dark brown, dry, cohesive.
	CL	4	24	9	99	66	28	SANDY CLAY; brown, dry, loose.
9.5'			37	16	100	87		SAME; grey.
14.0'	CH		58	30	100	81		SAME; cohesive.
	CL	13	46	23	100	86		SAME; moist.
		17	46	27	100	80	41	SAME
23.0'		21	49	27	100	88		SAME; fragments of cemented material.
27.0'	CH		50	34	100	79		SAME
30.0'								SAME
34.0'	CH		58	38	97	80		SANDY CLAY; brown, grey, and white, moist, cohesive, white streaks of cemented material.
37.0'	CL	17	34	18	98	61		SAME; red brown, moist, cohesive, cemented fragments.
42.0'								SAME; few gravel.
▽ 43.0'								SAME
44.0'	SC	13	32	13	65	13		CLAYEY, GRAVELLY SAND; grey to brown, wet, gravels to 1".

TH87 - 28

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
2.0'	SC		35	17	78	34		GRAVELLY, CLAYEY SAND; dark brown, dry, cohesive, gravel to 3".
6.0'	SP-SC		48	31	69	11		GRAVELLY SAND/CLAYEY SAND; light brown, moist, slightly cohesive, cobbles to 4"
	SW-SC	7	45	27	66	9		SAME; many cobbles to 4".
			45	27	66	9		SAME
			48	30	69	10		SAME; very dense.
			52	35	66	9		SAME
		9	44	26	66	10		SAME; many cobbles to 6".
20.0'			46	30	66	10		SAME
25.0'	SP-SC		50	33	66	11		SAME
	SC		46	28	69	16		CLAYEY, GRAVELLY SAND; light brown, moist, very dense, slightly cohesive, many cobbles to 6".
32.0'								SAME; cohesive.
36.0'	SW-SC		49	33	71	12		GRAVELLY SAND/CLAYEY SAND; light brown, moist, very dense, slightly cohesive, cobbles to 6".

NOTE: Stopped drilling due to large boulder.

SAFETY PAY

PI	-
4	9
24	9
29	7
10	9
7	9
15	10
33	10
18	10
30	10
48	10
12	9
32	10
37	10

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moist,
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f cobbles
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light brown,
obbles to 4"
brown,
cohesive,
light brown,
cohesive,
to large

TH87-26

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
2.0'	SM		19	4	97	46		SILTY SAND; light brown, dry.
5.0'	SC		41	24	97	20		CLAYEY SAND; dark brown, dry, cohesive.
7.0'	SW-SC		47	29	70	8	R	GRAVELLY SAND/CLAYEY SAND; brown, dry. SPT hit a rock.
10.0'	SC		25	10	98	42		CLAYEY SAND; light brown, dry, slightly cohesive.
13.0'	SM-SC		23	7	98	13	R	SILTY SAND/CLAYEY SAND; light brown, dry, loose. SPT hit a rock.
15.0'	CL	20	38	15	100	68		SANDY CLAY; light brown to grey, slightly cohesive.
19.0'	CH		61	33	100	97	22	CLAY; grey, moist, cohesive.
24.0'	CL	25	44	18	100	59		SANDY CLAY; grey to green, moist, cohesive.
29.0'	CH		52	30	100	97		CLAY; green/grey, moist, cohesive.
	CH	33	67	48	100	86		SANDY CLAY; green with grey and white streaks, moist, cohesive.
35.0'								SAME
38.0'	SC	14	28	12	99	29		CLAYEY SAND; green, moist, loose.
42.0'	CH		51	32	100	74		SANDY CLAY; green to brown, moist, cohesive.
▽ 44.0'								SAME; drilled through 0.5' layer of clean sand at 44'.
47.0'			58	37	100	81		SAME; wet.

NOTE: Stopped due to water causing hole to cave.

TH87-29

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
2.0'	SC		38	20	88	28		CLAYEY SAND; brown, dry, some gravel.
5.5'	SW-SC		47	30	69	10		GRAVELLY SAND/CLAYEY SAND; red to brown, dry, slightly cohesive, gravels to 3".
6.5'	SC	10	51	33	80	35		GRAVELLY, CLAYEY SAND;
	SW-SC		50	33	52	7		GRAVELLY SAND/CLAYEY SAND; brown, moist, slightly cohesive, gravel to 3".
		9	52	34	57	12		SAME
			45	26	61	7		SAME; clumps of clay.
		9	46	27	66	9		SAME
25.0'		10	50	31	64	11		SAME; no clumps of clay.
27.0'	SP-SC		48	29	62	11		SAME
30.0'	CH		67	48	100	53		SANDY CLAY; grey to brown, moist, rock-like chunks.
	SC		50	31	75	25		CLAYEY, GRAVELLY SAND; brown to grey, moist, some gravels, few cobbles to 4".
36.0'								SAME
40.0'	SW-SC		51	32	80	9		GRAVELLY SAND/CLAYEY SAND; brown, moist, slightly cohesive, cobbles to 4".
43.0'								SAME
	SW-SC		52	33	57	6		SAME
48.0'								SAME
51.0'	SP-SM			NP	84	6		GRAVELLY SAND/SILTY SAND, brown, moist, loose.
	SC		43	25	72	13		CLAYEY, GRAVELLY SAND; brown, moist, slightly cohesive.
								SAME
59.0'		16	43	24	75	13		SAME
	SC		56	34	98	33		CLAYEY SAND; grey with brown streaks, moist, cohesive, cemented pieces of material.
								SAME
68.0'		18	51	28	99	17		SAME; grey, clumps of clay.
70.0'	SW-SC		55	35	97	11		SAND/CLAYEY SAND; grey, moist, loose.
72.0'	SC	22	55	35	100	37		CLAYEY SAND; brown, moist, cohesive.

NOTES:

1. SEE PLATE 64 FOR LOCATION OF TEST HOLES.
2. SEE PLATE 36 FOR LEGEND AND CLASSIFICATION SYSTEM.
3. TEST HOLES WERE DRILLED USING A 24 BUCKET AUGER IN APRIL 1987.
4. THE DEPTH TO GROUNDWATER IS APPROXIMATE AND IS EXPECTED TO VARY SEASONALLY AND FROM YEAR TO YEAR.
5. THE LOG OF TEST HOLE INDICATES THE GEOTECHNICAL CONDITIONS AT THAT LOCATION AT THAT PARTICULAR TIME. SOIL CONDITIONS CAN CHANGE WITH TIME. THE STRATIFICATION LINES SHOWN ON THE LOGS REPRESENT THE APPROXIMATE BOUNDARY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL OR ABRUPT.

VERTICAL SCALE: 1 INCH = 5 FEET
SCALE 0 5 10 15 FEET

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
SOIL LOGS
BORROW AREA NO. 2
TH87-24 THROUGH TH87-29

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____-B-____
DISTRICT FILE NO.
SHEET

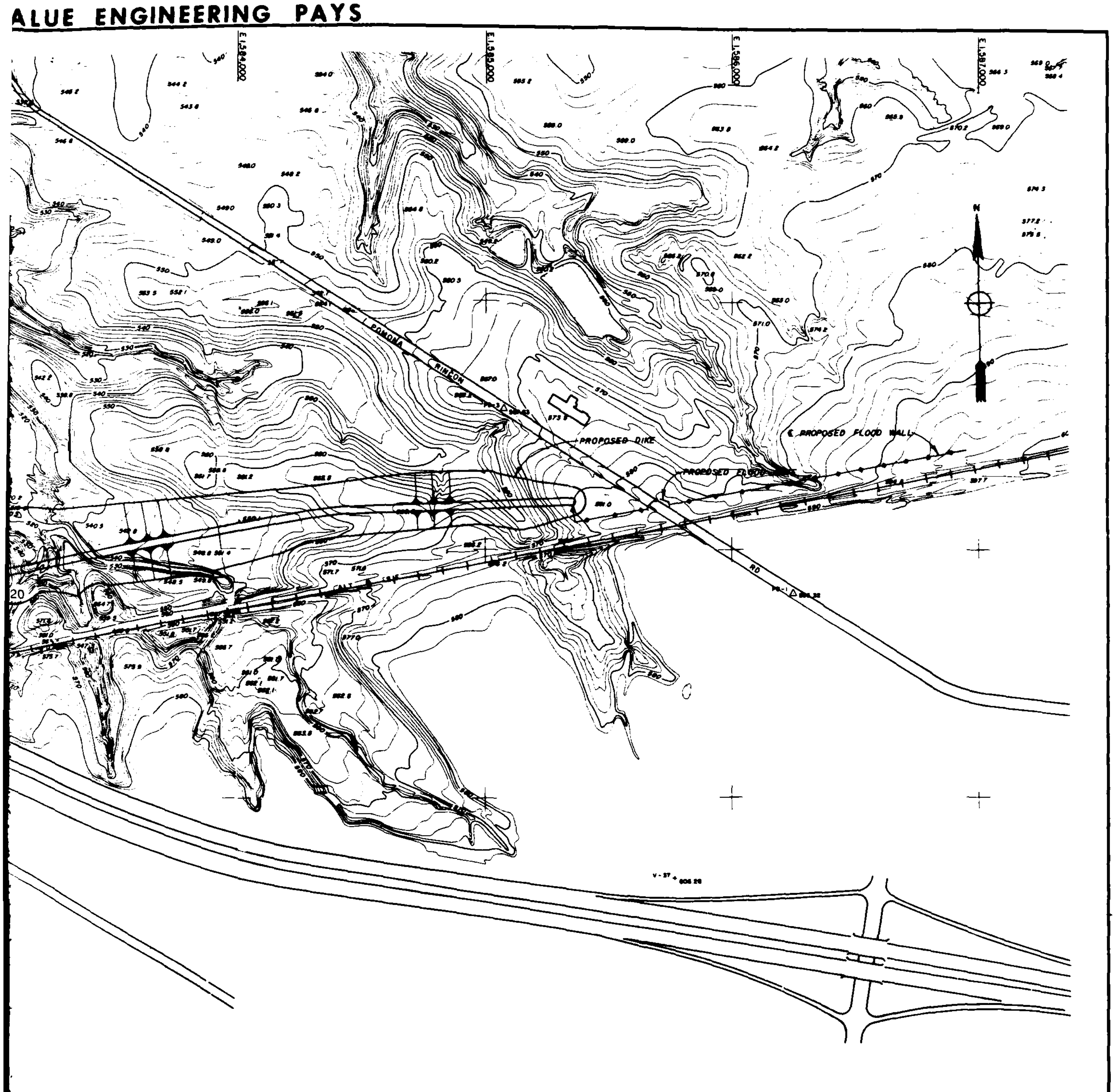
PLATE B-67

SAFETY PAYS

2

VALUE ENGINEERING

SAFETY PAYS



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FOUNDATION INVESTIGATION PLAN
AUXILIARY DIKE

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW 09-____ B-____
DISTRICT FILE NO.
SHEET

NOTE:
SEE PLATE 69 FOR SOIL LOGS.

SCALE: 1 IN. = 200 FT
100 0 100 200 300 400 500

PLATE B-68

1

2

VALUE ENGINEERI

TT 87-17

El.568 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	SC								CLAYEY SAND: brown, moist, some roots.
					98	49			no roots, very hard, hard clumps.
3.0'					87	39			dry, gravels to 1 in.
4.5'	GM				48	13			SILTY SANDY GRAVEL: brown, dry, very dense, subrounded gravels to 2 in.
	SC				96	43		28	CLAYEY SAND: brown, dry, dense.
11.0'		12.7	27	10	99	35		17	moist gravels to 1½ in.
12.0'	GP-GM				45	12			SANDY GRAVEL-SILTY SANDY GRAVEL: brown, moist, cobbles to 5 in.
	SC				98	42			CLAYEY SAND: brown, moist, slightly cohesive.
16.5'					89	19		17	

TT 87-18

El.575 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIP
3.0'	CL-ML		21	4	97	65		39	SANDY CLAY-SANDY SILT some roots, traces of to ¾ in.
	SC				68	26			CLAYEY GRAVELLY SAND. subrounded granite c
9.5'									SANDY CLAY: brown, mo composed granite.
10.0'	CL	8.2					[illegible]		
13.0'	SC		29	12	96	22		16	CLAYEY SAND: brown, s to 1 in., some decomp
14.5'	CL				99	67		21	SANDY CLAY: brown, mo

TT 87-20

El.568 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
1.0'	ML								SANDY SILT: brown, moist, some roots.
5.0'	CL								GRAVELLY SANDY CLAY: brown, dry, , very hard, gravels to 1½ in., clayey clumps of highly decomposed granite.
8.0'	SC		35	17	92	33			CLAYEY SAND: brown, dry, very dense, clayey clumps of highly decomposed granite.

TT 87-21

El.557 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRI
1.0'	ML								SANDY SILT: brown, mo gravel.
3.0'	SC		28	11	99	32			CLAYEY SAND: brown, s stiff.
5.0'	CL		29	8	100	65	92.0		SANDY CLAY: light br and dark brown blotc lenses of sand and d

TH 87-13

El.571 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	CL		36	19	97	51			SANDY CLAY: reddish brown, damp, stiff to very stiff.
								R	hard, gravel to 3 in., cobbles to 5 in.
6.0'									
	SC		28	11	98	39		[illegible]	CLAYEY SAND: reddish brown with small white streaks, damp, very dense.
								41	some gravel.
13.5'		7.0	28	9	100	49	97.0	37	yellowish brown, few gravel to 3 in.
	SM				96	24		36	SILTY SAND: yellowish brown, damp, few gravel to 3 in., some caving below 15 ft
20.0'									SILTY GRAVELLY SAND: yellowish brown, damp, gravel to 2 in.
23.5'	SP-SM				79	7		60+	GRAVELLY SAND-SILTY GRAVELLY SAND: yellowish brown, damp, gravel to 3 in.
25.5'	SM				97	32			SILTY SAND: yellowish red-brown with grey, moist, some cohesion.
	SP-SM				64	8			GRAVELLY SAND-SILTY GRAVELLY SAND: damp to moist, gravel to 3in.
					60	5			yellowish brown, moist.
36.0'					68	6			damp, beige.
	SW-SM				77	7			GRAVELLY SAND-SILTY GRAVELLY SAND: beige, gravel to 3 in.
41.0'									beige to rust, medium dense.

TH 87-15

El.574 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESC
1.0'	CL								SANDY CLAY: reddish medium.
	ML		26	3	100	74			SANDY SILT: light br
6.0'								50	brown, damp.
9.0'	CL-ML	4.7	28	7	100	73		58	SANDY CLAY- SANDY SI
	SM				73	19		R	SILTY GRAVELLY SAND: damp, dense.
14.5'		2.6			67	14			light brown, gravel to to 4 in.
15.0'	SP-SM	4.2			61	5			GRAVELLY SAND-SILTY G brown, damp, loose, extr

SAFETY PA

LUE ENGINEERING PAYS

TT 87-18

PI	-4	-200	γ_d	N	DESCRIPTION
4	97	65		39	*SANDY CLAY-SANDY SILT: brown,moist, some roots,traces of decomposed granite to ¼ in.*
	68	26			*CLAYEY GRAVELLY SAND: brown,very dense, subrounded granite cobbles to 4 in.*
			[illegible]	16	*SANDY CLAY: brown,moist,traces of decomposed granite.*
12	96	22			*CLAYEY SAND: brown,slightly moist,gravel to 1 in.,some decomposed granite.*
	99	67		21	*SANDY CLAY: brown,moist.*

TT 87-19

EL557 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
1.0'	ML				98	60			*SANDY SILT: brown,moist.*
	CL								*SILTY CLAY: light brown with rust and dark brown blotches,moist,hard.*
6.0'		17.5	39	15	100	92			
9.0'	SC				94	14			*CLAYEY SAND: brown,slightly moist, gravels to 1½ in.,decomposed granite present in coarse sand sizes.*
12.0'	SW-SM	2.5			70	6			*GRAVELLY SAND-SILTY GRAVELLY SAND: brown,moist,gravel to 3/4 in., material is loose.*

TT 87-21

PI	-4	-200	γ_d	N	DESCRIPTION
					SANDY SILT: brown,moist,occasional gravel.
11	99	32			*CLAYEY SAND: brown,slightly moist, stiff.*
8	100	65	92.0		*SANDY CLAY: light brown with rust and dark brown blotches,moist,hard, lenses of sand and decomposed granite.*

TT 87-22

EL585 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
2.0'	ML		21	2	99	70			*SANDY SILT: dark brown,moist,some cohesion,roots in top 4 in.*
	CL				100	62		31	*SANDY CLAY: reddish brown,moist, occasional gravel.*
		13.0	47	28	100	86	103.1	33	*CLAY: light to dark brown,moist.*
8.0'			33	16	99	61			*SANDY CLAY: brown,moist,some cohesion.*
	SM			NP	99	47		18	*SILTY SAND: brown,moist,some cohesion.*
13.5'									

TH 87-15

PI	-4	-200	γ_d	N	DESCRIPTION
3	100	74			*SANDY CLAY: reddish brown,moist, medium.*
					SANDY SILT: light brown,dry,medium.
				50	*brown,damp.*
7	100	73		58	SANDY CLAY- SANDY SILT: *light brown,dry.*
	73	19		R	*SILTY GRAVELLY SAND: yellowish grey, damp,dense.*
	67	14			*light brown,gravel to 3in.,few cobbles to 4 in.*
	61	5			*GRAVELLY SAND-SILTY GRAVELLY SAND: light brown,damp,loose,extreme caving.*

NOTES:

1. TEST TRENCHES WERE EXCAVATED WITH A BACKHOE IN JANUARY 1987.
2. TEST HOLES WERE DRILLED WITH A 24-INCH BUCKET AUGER IN JANUARY 1987
3. SEE PLATE 34 FOR LEGEND AND CLASSIFICATION SYSTEM.
4. SEE PLATE 48 FOR TRENCH AND HOLE LOCATIONS.

SCALE: 1IN= 5 FT.
5 0 5 10 15

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY.
DRAWN BY.
CHECKED BY.

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

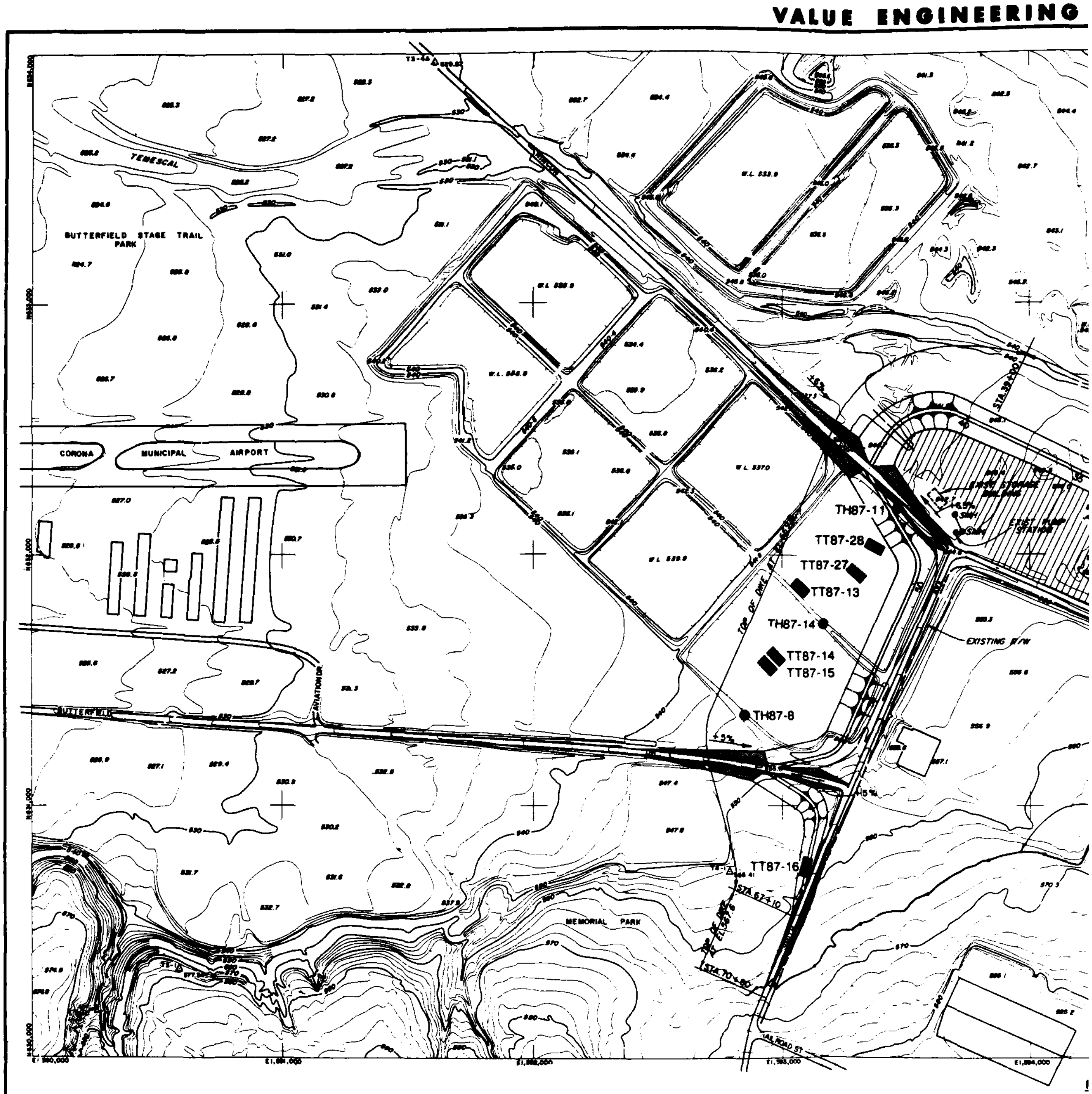
FOUNDATION SOIL LOGS
AUXILIARY DIKE

SUBMITTED BY.
DATE APPROVED.
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-60

SAFETY PAYS

2


TEMESCAL
BUTTERFIELD STAGE TRAIL PARK
CORONA MUNICIPAL AIRPORT
BUTTERFIELD
AVIATION DR.
MEMORIAL PARK
W.L. 537.0
TH87-11
TT87-28
TT87-27
TT87-13
TH87-14
TT87-14
TT87-15
TH87-8
TT87-16
TOP OF DIKE
STA 39+00
STA 67+10
STA 70+80
EXIST STORAGE BUILDING
EXIST PUMP STATION
EXISTING R/W
+5%
RAIL ROAD ST
E1,590,000
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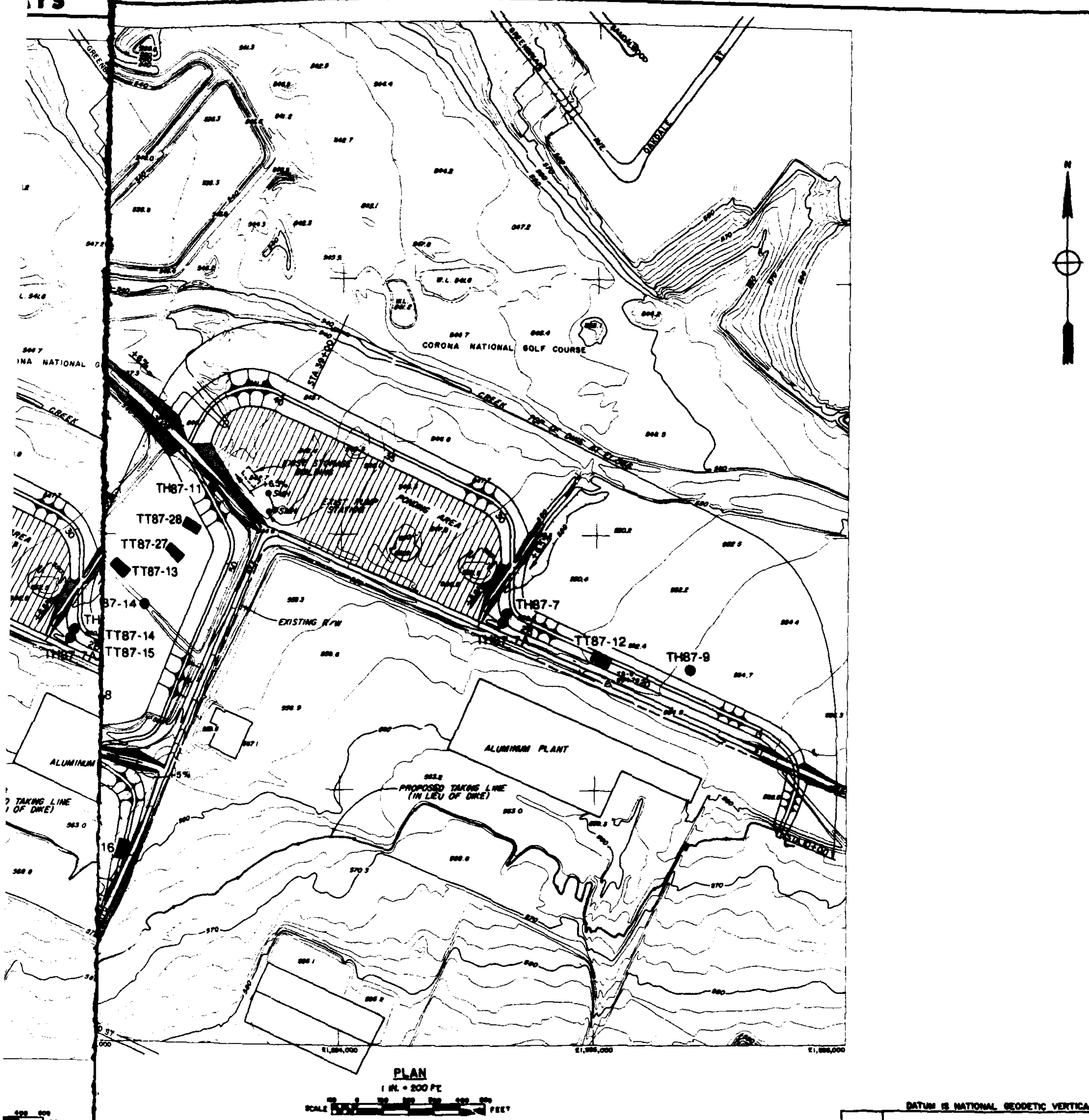
SCALE
1 IN



PLAN

1 IN. = 200 FT.

NOTE:

SEE PLATES 71 AND 72 FOR SOIL LOGS

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FOUNDATION INVESTIGATION PLAN
DIKE AT ALCOA ALUMINUM PLANT

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-70

2

VALUE ENGIN

TT 87-12

EL. 553 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	SM				93	37			SILTY SAND: brown, moist, gravels to 1 in.
4.0'									light brown with red streaks.
5.5'	CL	18.5	38	16	100	71	82.6		SANDY CLAY: dark brown, with red streaks of clay, moist.
8.5'	SM	6.9					98.0		SILTY SAND: reddish brown, moist.
9.5'	CL		37	13	98	95			CLAY: grey with red streaks, moist.
11.5'	SM								SILTY SAND: red'ish brown, moist.
12.0'	CL								CLAY: dark grey with red streaks, moist, cohesive.
▽ 14.5'	SM				72	14			SILTY GRAVELLY SAND: brown, moist, gravels to 3 in., few cobbles to 4 in.
15.0' 16.0'	CH				98	71			SANDY CLAY: grey-green with brown streaks, wet, 2 in. layer of grey sand at 15.5 ft.

TT 87-13

EL. 540 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
1.5'	SM								SILTY SAND: dark brown, moist.
4.5'	CL				97	58			SANDY CLAY: reddish brown, moist.
6.0'	ML	10.3			97	53	121.4		SANDY SILT: brown, moist, gravels to to 1 in.
9.0'	GP-GM				40	11			SANDY GRAVEL-SILTY SANDY GRAVEL: brown, moist, subangular, cobbles to 6 in.
▽ 10.5'	CL		35	15	98	86			CLAY: reddish brown, moist.
12.5'					99	78			SANDY CLAY: reddish brown, wet.

TT 87-16

EL. 558 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	SC	12.1							CLAYEY SAND: dark brown, moist, loose with some cohesion.
3.0'		3.6	33	13	90	39	118.3		brown, gravels to 1/2 in.
5.0'	SW-SC				80	9			GRAVELLY SAND-CLAYEY GRAVELLY SAND: reddish brown, moist.
8.0'	CL	12.8			99	67			SANDY CLAY: reddish brown, moist, some cohesion.
	SM				85	46			GRAVELLY SILTY SAND: brown with some grey, moist, gravels to 1.5 in., loose.
14.0'									gravels to 2 in.

TT 87-27

EL. 540 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
3.0'	ML				99	66			SANDY SILT: dark brown, damp.
6.0'	SM								SILTY SAND: light reddish brown, damp.
9.5'	SW-SM	8.1			80	9			GRAVELLY SAND-SILTY GRAVELLY SAND: light brown, damp, few cobbles to 6 in., gravel to 2 in.
▽ 10.5' 11.0'	CL				100	89			CLAY: reddish brown, wet, sand layer above caved in.

TH 87-7

EL. 550 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	ML								SANDY SILT: brown, moist, few gravels to 3/8 in.
								12	no gravel.
7.0'								13	
9.0'	SP-SM				75	7			GRAVELLY SAND-SILTY GRAVELLY SAND: brown, moist, gravel to 1 in.
11.5'	SC	16.7	29	11	99	27	108.5	8	CLAYEY SAND. brown, moist, gravel to 2 in.
▽ 12.5' 17.0'	SW-SM				74	9			GRAVELLY SAND-SILTY GRAVELLY SAND: brown, subangular gravels, cobbles to 4 in.
	SM								SILTY SAND: brown, moist, few gravel.
18.0'									SILTY GRAVELLY SAND: brown, gravel to 1 in., encountered boulder.

TH 87-7A

DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
19.0' 22.0'	SC		23	8	72	14			CLAYEY GRAVELLY SAND: brown, gravel to 3 in.
27.0'	GC				56	13			CLAYEY SANDY GRAVEL: brown, subangular gravel to 1-1/2 in.
28.0'	GW				29	1			SANDY GRAVEL: brown, subangular gravel.
30.0'	SC								CALYEY GRAVELLY SAND: brown, subangular gravel to 1-1/2 in.
	CH	57.7	96	70	96	78			SANDY CLAY: green-grey with green and rust colored blotches.
								19	
40.0'								25	

SAFETY

TT 87-14

EL. 540 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
2.0'	ML								SILTY SAND: dark brown, moist.
	CL		28	11	98	56		6	SANDY CLAY: reddish brown, moist.
		16.8			100	62	104.6	5	
									wet.
▽ 11.0'			27	10	100	58			
15.0'									

TT 87-15

EL. 540 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
2.0'	ML				98	73			SANDY SILT: dark brown, moist.
	CL								SANDY CLAY: reddish brown, moist.
7.0'		17	30	11	100	64	98.0		

TT 87-28

EL. 540 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	SP								SAND: brown, damp.
									light brown.
		4.2		NP	87	1			gravel to 2.5 in.
▽ 9.5'									wet, trench caved in.
11.0'									

NOTES:

1. TEST TRENCHES WERE EXCAVATED WITH A BACKHOE IN JANUARY 1987.
2. TEST HOLES WERE DRILLED WITH A 24-INCH BUCKET AUGER IN JANUARY 1987.
3. SEE PLATE 36 FOR LEGEND AND CLASSIFICATION SYSTEM.
4. SEE PLATE 70 FOR TRENCH AND HOLE LOCATIONS.

TH 87-8

EL. 546 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	CL		30	11	99	63			SANDY CLAY: brown, moist.
6.0'	SC							15	CLAYEY SAND: brown, slightly moist, occasional gravel to 3/4 in.
		14.8	25	8	100	46	104.7	8	
13.5'									soft
	SC-SM							5	CLAYEY SAND-SILTY SAND; brown, soft.
▽ 16.5'		17.1	22	5	100	41			
	CL	19.8	34	15	100	63			SANDY CLAY. brown, soft.
								5	
								3	
32.0'					99	78		6	
33.0'	CL-ML		23	6	98	53			SANDY CLAY-SANDY SILT: grey, few gravels to 3/4 in.
36.0'	GM				40	15			SILTY SANDY GRAVEL: grey-brown, subangular gravel to 3 in., cobbles to 4 in.

SCALE: 1 IN. = 5FT.

5 0 5 10 15

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FOUNDATION SOIL LOGS
DIKE AT ALCOA ALUMINUM PLANT
TT 87-12 THRU TT 87-16, TT87-28
TH 87-7, TH 87-7A, TH 87-8

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

TH 87-9

EL.564 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
3.0'	SM	41			89	19			SILTY SAND: brown, damp.
8.0'	SP			NP	83	4		8	GRAVELLY SAND: brown, gravel to 2in., some caving at 4 ft.
11.0'	CL	34.2						12	SANDY CLAY: brown with red, moist, cohesive.
13.5'	SM	6.4							SILTY SAND: reddish brown, moist, gravel to 1 in.
16.0'		21.8		NP	99	34	75.9	10	occasional gravel to 3 in.
	SP				83	4			GRAVELLY SAND: brownish grey, gravels to 3 in.
23.0'									cobbles to 5 in.
27.0'	SC				96	47		12	CLAYEY SAND; brown, cohesive.
30.0'	SM				98	17			SILTY SAND: greyish brown, few cobbles to 12 in.
	SW-SM				75	11			GRAVELLY SAND-SILTY GRAVELLY SAND: brown, gravels to 2in.
40.0'									some cobbles to 6 in.

TH 87-11

EL.545 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
1.5'	SM	8.2							SILTY SAND: dark brown, damp to moist, few gravel to 1/2 in.
3.0'	ML	16.9			89	71			SANDY SILT: brown, moist, some cohesion.
5.5'	SW-SM	2.9			91	8			SAND-SILTY SAND: brown, damp, loose gravel to 1 in.
8.5'	SW-SC	6.2	20	5	89	12		9	SAND-CLAYEY SAND: brown, damp, gravel to
10.0'	SP	3.5							SAND: light brown, moist, few gravel to
11.5' ▽	SP-SM				85	6		8	GRAVELLY SAND-SILTY GRAVELLY SAND: light brown, saturated, gravel to 1 in.
17.0'									few gravel to 2 in.
21.0'	SP				96	4		6	SAND: light brown, gravel to 3 in.
	SC		31	12	79	46			GRAVELLY CLAYEY SAND: brown, moist, gravel to 1 in.
27.0'									gravels to 3 in.
30.0'	SP-SM				62	7			GRAVELLY SAND-SILTY GRAVELLY SAND: brown with black and white, saturated, loose, gravel to 3 in., few cobbles to 6 in.
34.0'	GP-GM				51	6			SANDY GRAVEL-SILTY SANDY GRAVEL: brow black and white, loose, gravel to 3 in., 20% cobbles to 12in.

end of boring due to cobbles.

TH 87-11

LL	PI	-4	-200	γ_d	N	DESCRIPTION
						SILTY SAND: dark brown, damp to moist, few gravel to 1/2 in.
		99	71			
		91	5			SANDY SILT: brown, moist, some cobbles.
20	5	89	12		9	SAND-SILTY SAND: brown, damp, loose gravel to 1 in.
						SAND-CLAYEY SAND: brown, damp, gravel to 1 in.
						SAND: light brown, moist; few gravel to 1 in.
		85	6		8	GRAVELLY SAND-SILTY GRAVELLY SAND: light brown, saturated, gravel to 1 in.,
						few gravel to 2 in.
		86	4		6	SAND: light brown, gravel to 3 in.
31	12	79	46			GRAVELLY CLAYEY SAND: brown, moist, gravel to 1 in.
						gravels to 3 in.
		62	7			GRAVELLY SAND-SILTY GRAVELLY SAND: brown with black and white, saturated, loose, gravel to 3 in., few cobbles to 5 in.
		51	8			SANDY GRAVEL-SILTY SANDY GRAVEL: brown, black and white, loose, gravel to 3 in., 30% cobbles to 12in.

end of boring due to cobbles.

TH 87-14

EL. 546 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	CL								SANDY CLAY: no sample taken.
								16	SILTY CLAY: dark brown, moist.
									more silty, damp.
9.0'								15	moist.
11.0'	ML								SANDY SILT: moist, dark brown, soft.
	CL	208	33	14	100	85		0	SANDY CLAY: dark brown, very moist, soft.
18.0'		299						0	CLAY: dark brown, very moist, soft, strong odor, 4 in. lense of silty sand at 15 ft.
21.0'	ML							0	SANDY SILT: dark brown, very moist, soft, slight odor.
25.0'	CL							0	SILTY CLAY: dark brown, very moist, soft, trace of pea gravel.
28.0'	GC				46	16			CLAYEY SANDY GRAVEL: dark brown, wet, loose, some cobbles to 5 in.
	GP-GC				29	6			SANDY GRAVEL-CLAYEY SANDY GRAVEL: dark brown, wet, loose to medium dense, cobbles to 5 in.
					48	7			blackish brown, medium dense some cobbles to 4 in.
35.0									more clay, more cobbles.
38.0	SW-SM		20	3	67	8			GRAVELLY SAND-SILTY GRAVELLY SAND: greyish light brown, wet, medium dense, few gravel to 1 1/2 in.
42.0	SP-SM				63	11			GRAVELLY SAND-SILTY GRAVELLY SAND: brown, wet, medium dense, few cobbles to 4 in.
	SW-SM				75	6			GRAVELLY SAND-SILTY GRAVELLY SAND: brown, wet, medium dense.
									less fines and gravel.
50.0'									

NOTES:

1. TEST HOLES WERE DRILLED WITH A 24 - INCH BUCKET AUGER IN JANUARY 1987.
2. SEE PLATE B-1 FOR LEGEND AND CLASSIFICATION SYSTEM.
3. SEE PLATE B-70 FOR TEST HOLE LOCATIONS.

SCALE 1 IN. = 5 FT.

SCALE 5 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

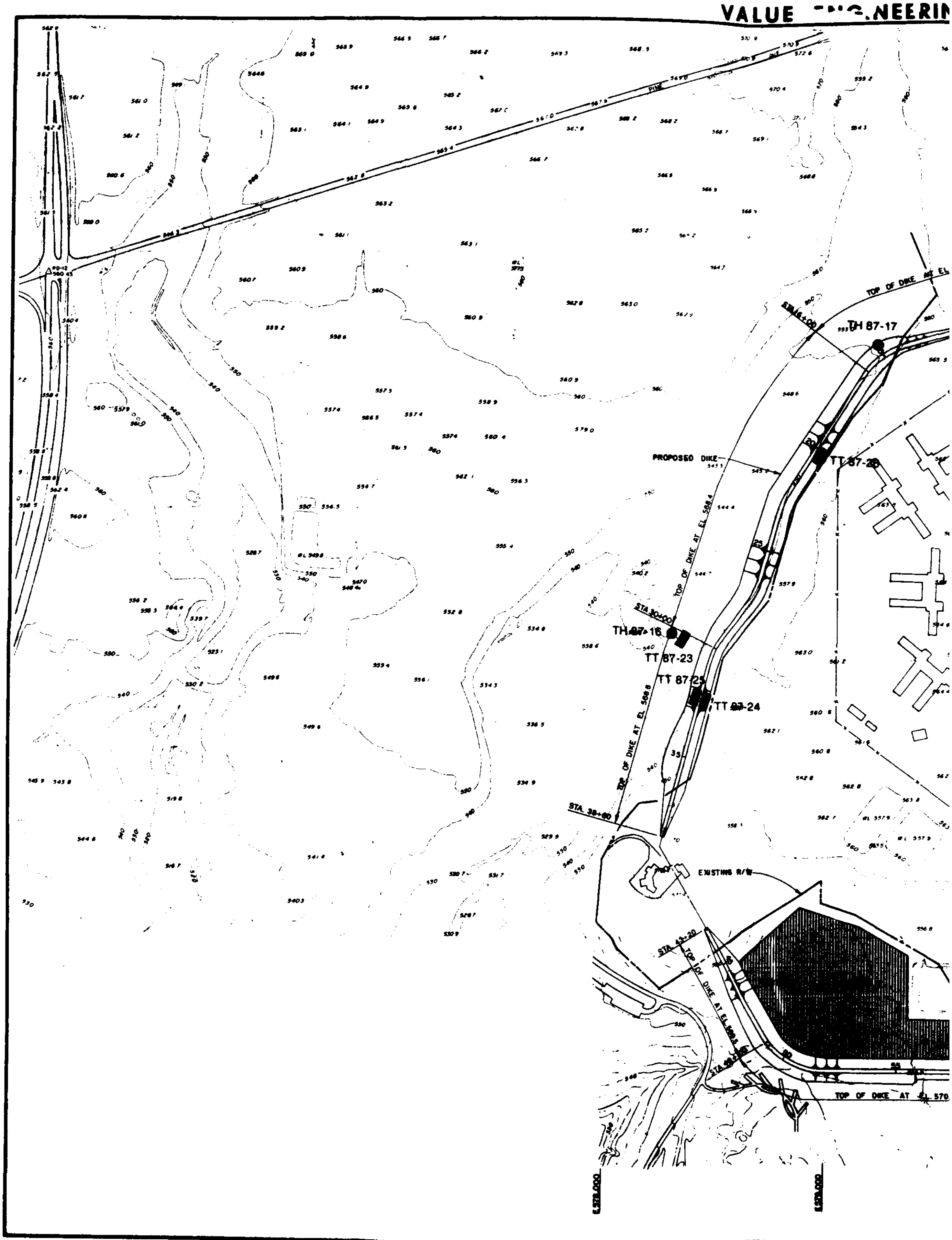
FOUNDATION SOIL LOGS
DIKE AT ALCOA ALUMINUM PLANT
TH 87-9, TH 87-11, TH 87-14

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET

PLATE B-72

2

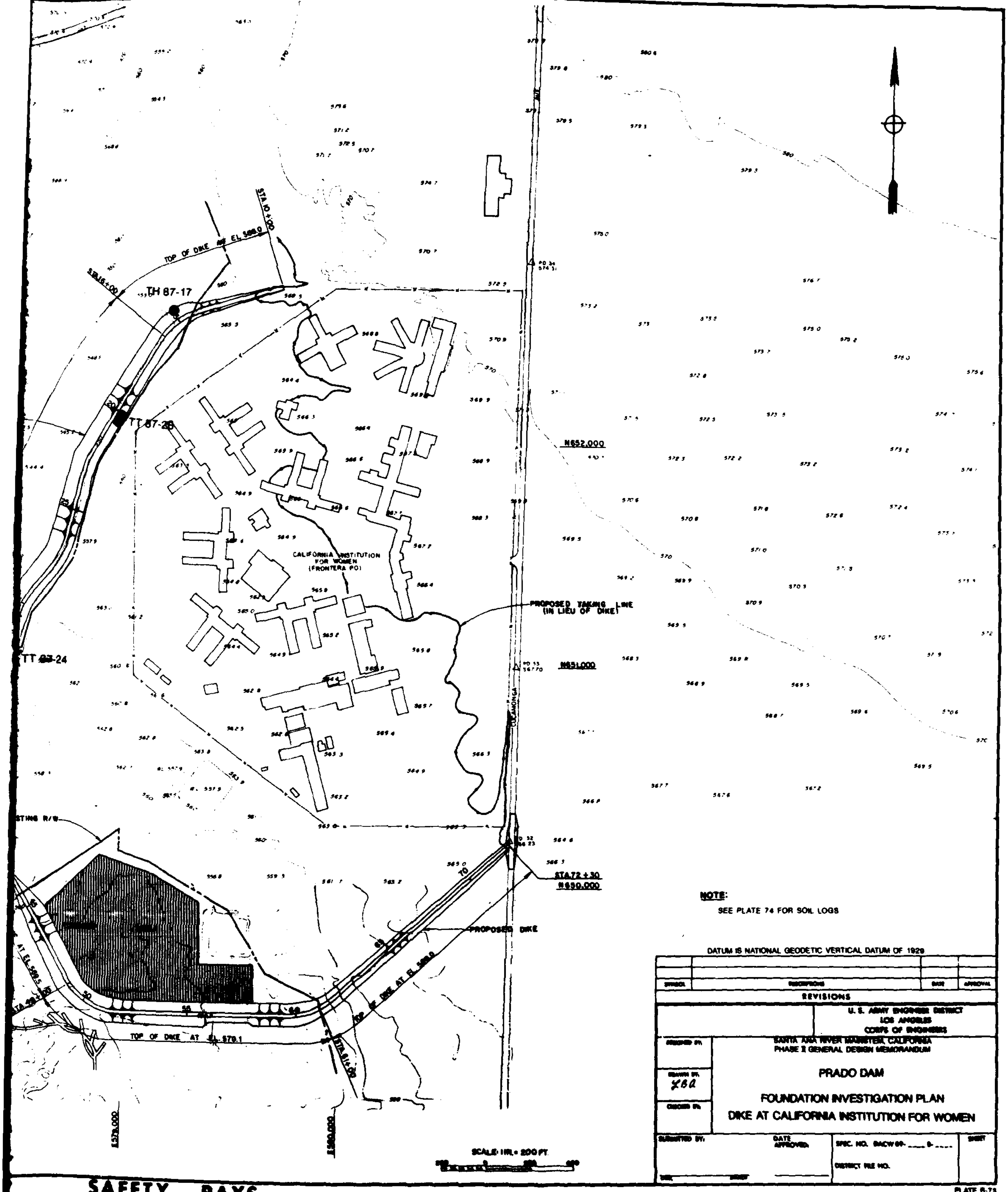
VALUE ENGINEERIN



SAFETY PA

1

VALUE ENGINEERING PAYS



NOTE:

SEE PLATE 74 FOR SOIL LOGS

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

DESIGNED BY:

DRAWN BY: ZBA

CHECKED BY:

PRADO DAM

FOUNDATION INVESTIGATION PLAN

DIKE AT CALIFORNIA INSTITUTION FOR WOMEN

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

PLATE B-73

SAFETY PAYS

1

2

TT 87-23

El.540 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
1.5'	SM								SILTY SAND: dark brown, moist, some roots.
	MH	88.0	78	30	100	93			SILT: grey, moist, some cohesion:
								2	wet, perched water from 3.8 ft. to 7 ft.
7.0'					100	97			brown to grey with red streaks.
	OH	246.0	180	51	100	86			ORGANIC SILT: black with red streaks (roots), moist, loose.
13.0'								2	
16.0'	MH				100	84			SANDY SILT: grey, moist, organics present.

TT 87-24

El.554 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
1.0'	SM								SILTY SAND: brown, damp,
	CH		64	43	99	82			SANDY CLAY: light brown, many clods.
		23.8	87	60	99	87	98.9	16	CLAY: light green with bi white, hard material, dr stiff.
		23.6			100	86	75.2		green with a 2 in. lense CH at 8.0 ft.
			58	40	100	83		16 11	SANDY CLAY: reddish green
					94	79			light brown.
16.5' ▽									

TT 87-26

El.5[illegible] DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
1.5'	ML	34.3							CLAYEY SILT: dark brown, damp, surface vegetation and roots in 4 in.
	CL		45	27	100	79			
		16.4	42	24	100	72	131.3		SANDY CLAY: dark brown, damp, large chunks.
		15.2	39	22	99	62			light brown, moist.
									light reddish brown, damp.
		15.1					142.6		occasional gravel.
					100	94			SILTY CLAY: light brown, moist, some cohesion.
14.5'									
16.5' ▽									

TH 87-16

El.540 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
		60.2			100	86			ORGANIC SILT: dark brown damp to moist, some roots
	OH	98.8	119	56	100	96	40.2		black, moist to wet, soft water at 4 ft.
5.5'								5	
7.0'	MH	44.1			100	94			SILT: grey, moist.
	OH	205.0	191	57	100	99			ORGANIC SILT: black, mois spongy.
		332.5			100	98			some brown plant fiber,
								0	some grey silt marbled th
15.0'		216.7							
16.0'	ML	32.3			100	52			SANDY SILT: grey, moist, no odor.
18.0'	SM	30.8			100	27		6	SILTY SAND: rusty light b moist, loose.
19.0'	CL-ML	27.4	26	4	100	69			SANDY CLAY-SANDY SILT: li moist.
	ML	26.8			100	56			
		29.8							SANDY SILT: light brown, loose.
24.0'									
25.0'	SC	33.9							SILTY CLAYEY SAND: light moist, loose.

LUE ENGINEERING PAYS

S

TT 87-24

LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
SM								SILTY SAND: brown, damp, few roots.
CH		64	43	99	82			SANDY CLAY: light brown, dry, stiff, many clods.
	23.8	87	60	99	87	98.9	16	CLAY: light green with bits of white, hard material, dry, very stiff.
	23.6			100	86	75.2		green with a 2 in. lense of red CH at 6.0 ft.
		58	40	100	83		16 11	SANDY CLAY: reddish green, damp.
				94	78			light brown.

TT 87-25

El.540 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
1.0'	SM								SILTY SAND: brown, dry;
2.0'	MH				100	93			SILT: dark grey with thin lenses of white material, dry.
	CH	30.2	50	25	100	88	82.5		CLAY: dark brown, damp.
6.0'			62	42	100	89			reddish green.

TH 87-16

LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
	60.2			100	86			ORGANIC SILT: dark brown to black, damp to moist, some roots.
OH	96.8	119	56	100	96	40.2	5	black, moist to wet, soft, perched water at 4 ft.
MH	44.1			100	94			SILT: grey, moist.
OH	206.0	191	57	100	99			ORGANIC SILT: black, moist, soft, spongy.
	338.5			100	98			some brown plant fiber, odor.
	216.7						0	some grey silt marbled throughout.
ML	32.5			100	52			SANDY SILT: grey, moist, loose, no odor.
SM	30.8			100	27		6	SILTY SAND: rusty light brown, moist, loose.
CL-ML	27.4	26	4	100	69			SANDY CLAY-SANDY SILT: light brown, moist.
ML	26.8			100	58			SANDY SILT: light brown, moist, loose.
	25.8							
SC	33.9							SILTY CLAYEY SAND: light brown, moist, loose.

TH 87-17

El.594 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
2.0'	OH	44.3			100	85			SANDY ORGANIC SILT: dark brown to black, damp, soft, some roots.
4.0'	MH	35.4							CLAYEY SILT: light brown with black lenses, damp, soft.
	OH	81.5	92	37	100	76			ORGANIC SILT: black, damp, low density, very soft.
8.0'		30.4						2	dark grey to black.
10.0'									No Sample Taken.
	ML				100	55		4	SANDY SILT: grey, moist, low density, some cohesion.
15.0'		22.8			100	62			brown, damp.
	CL-ML	24.9	24	4	100	58	108.4	5	SANDY CLAY-SANDY SILT: light brown, damp.
		21.7	25	5	100	68			
22.0'		23.7			100	55			moist.
24.0'	CH				100	93			CLAY: very light brown, very cohesive.
26.0'	CL	30.4	38	19	100	70	81.7		SANDY CLAY; very light brown, very cohesive.

NOTES:

1. TEST TRENCHES WERE EXCAVATED WITH A BACKHOE IN JANUARY 1987.
2. TEST HOLES WERE DRILLED WITH A 24-INCH BUCKET AUGER IN JANUARY 1987.
3. SEE PLATE 36 FOR LEGEND AND CLASSIFICATION SYSTEM.
4. SEE PLATE 73 FOR TRENCH AND HOLE LOCATIONS.

SCALE: 1 IN = 5 FT.
5 0 5 10 15

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FOUNDATION SOIL LOGS
DIKE AT CALIFORNIA INSTITUTION FOR WOMEN

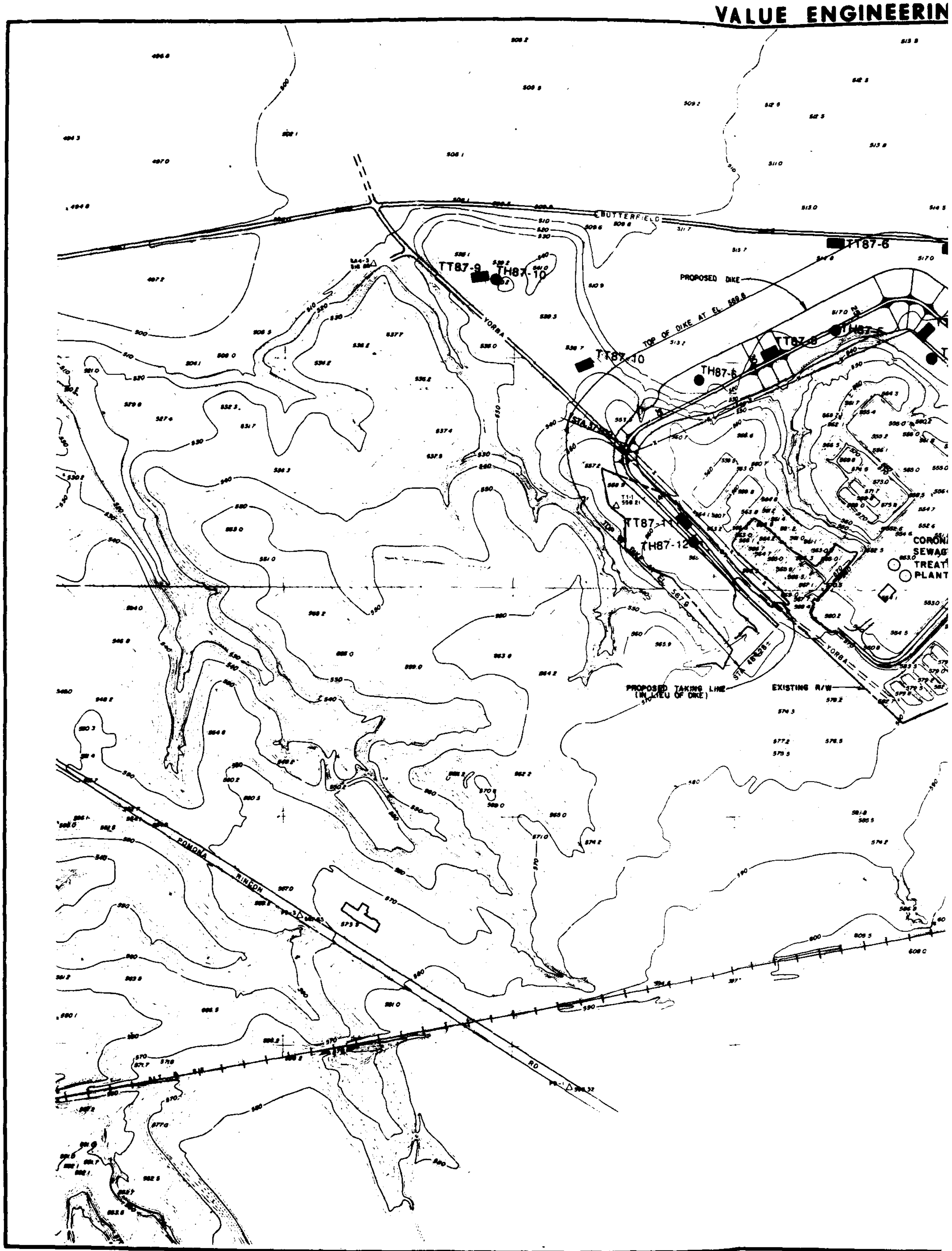
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09- ____ B- ____
DISTRICT FILE NO.
SHEET

SAFETY PAYS

PLATE B-74

2

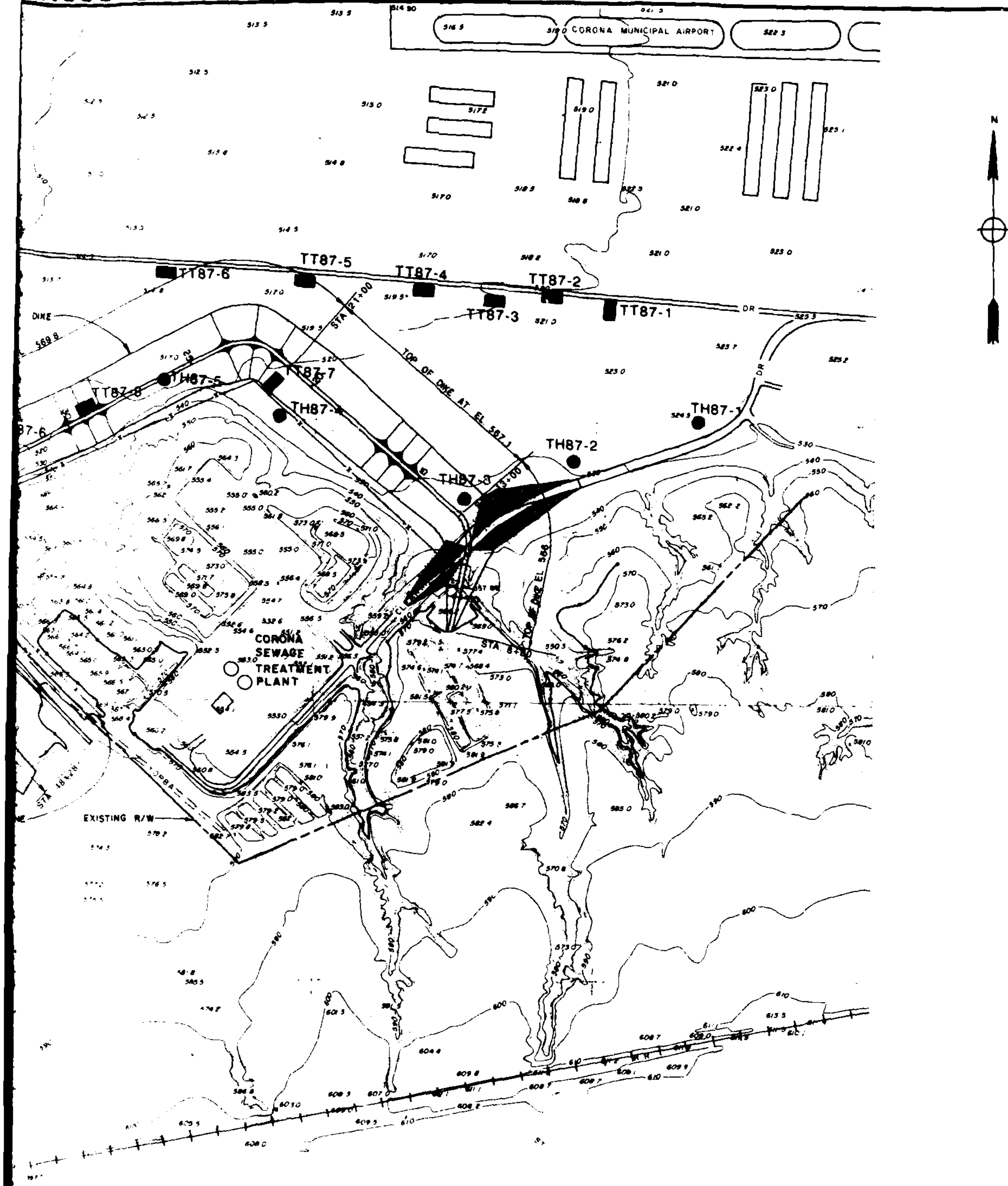
VALUE ENGINEERIN



SAFETY PA

1 1

VALUE ENGINEERING PAYS



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPRO

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY: LBa

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FOUNDATION INVESTIGATION PLAN
DIKE AT CORONA SEWAGE TREATMENT PLANT

SUBMITTED BY:

DATE APPROVED

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

PLATE 2

NOTE:
SEE PLATES 76 AND 77 FOR SOIL LOGS

SCALE: 1 IN.= 200 FT.
200 0 200 400

SAFETY PAYS

VALUE ENGINEERI

TT87-1

EL 528 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
1.5'	SM	6.6			63	25			GRAVELLY SILTY SAND: brown, moist, occasional cobble to 4 in., some roots, slightly cohesive.
2.5'	CL	16.5	44	23	100	94			CLAY: brown with grey blotches, moist.
5.5' ▽	CL-ML	23.6	28	6	100	59			SANDY CLAY-SANDY SILT: grey, very wet.
10.0'	CL				98	73			SANDY CLAY-brown with few grey blotches, very wet.

TT87-2

EL 531 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
1.5'	SM	4.1							SILTY SAND: brown, moist, some chunks of clayey sand, gravels and cobbles to 8 in. Top 0.5 ft. of soil.
3.0'	ML	10.6			90	51			SANDY SILT: brown, moist, dense, chunks of clayey sand gravels to 1 in.
6.0'	CL	13.6							SANDY CLAY: brown – grey intermixed, very moist, stiff, few gravel to 1 in.
7.0' ▽									

TT87-5

EL 517 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
	CL	4.3							SANDY CLAY: dark brown, moist, gravels to 1 in., some blotches of brown, plastic clay.
		7.8							cobbles to 8 in.
		14.9	30	8	96	67	86.5		grey mottled with brown, no gravels or cobbles.
7.0' ▽		17.1							very moist.
11.0'									

TT87-6

EL 515 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
	CL	17.9	27	9	100	85			SANDY CLAY: brown-grey intermixed, moist, some roots.
		12.6							no roots.
		20.9	27	8	99	53	106.4		dark grey-brown intermixed, very moist.
6.5' ▽					100	80			wet.
10.0'									

TT87-9

EL 538 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
	ML								SANDY SILT: brown, moist, cohesive.
2.0'		9.1							dry to moist, few gravels to 1½ in.
	SM								SILTY GRAVELLY SAND: brown, dry to moist, cobbles to 5 in., clumps of gravels and soil.
		12.2					114.2		moist, gravels to 3 in.
		7.3			72	19			
15.0'		4.8							

TT87-10

EL 539 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
1.0'	ML								SANDY SILT: dark brown, moist, some roots.
2.5'	CL				99	76			SANDY CLAY: brown, moist.
3.5'	SP-SC		36	19	98	12			SAND-CLAYEY SAND: tan to brown, moist.
6.0'	CL		27	13	80	57			GRAVELLY SANDY CLAY: brown, moist, gravels to 2 in.
12.5'	GC	7.4			39	28			CLAYEY GRAVEL: brown, moist, gravels to 3 in.
15.5'	CL	5.1							GRAVELLY SANDY CLAY: brown, moist.
16.5'	SP	8.8			98	4			SAND: brown, moist, few gravels to ½ in.

TH87-1

EL 525 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
3.0'	CL-ML	21.3	24	4	98	62			SANDY CLAY-SANDY SILT: dark brown, moist, few gravels.
4.5' ▽ 5.5'	SC	26.4	28	9	97	34			CLAYEY SAND: dark brown, wet, few gravels.
	CL	17.8							SANDY CLAY: dark brown, wet.
		11.1			99	66			reddish brown.
		20.8							
			33	17	100	63			
					98	57			
17.5'			31	11	100	67			
18.0'	SC				63	[illegible]			CLAYEY GRAVELLY SAND: brown, wet, gravels to 2 in.
	SP-SC				81	6			GRAVELLY SAND-CLAYEY GRAVELLY SAND, brown, wet, gravel to 3 in.
23.0'									Subangular cobbles to 5 in.
25.5'	ML	30.7	36	11	80	59			GRAVELLY SANDY SILT: brown.
27.5'	SW-GM				48	10			SANDY GRAVEL-SILTY SANDY GRAVEL: brown, wet, subangular to subrounded gravels to 2 in.
30.0'	SW-SM				53	6			GRAVELLY SAND-SILTY GRAVELLY SAND: brown, wet, subangular gravel to 3 in.

TH87-2

EL 528 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
	ML	10.3							SANDY SILT: reddish brown, gravels to 1 in.
				NP	98	65			
					98	67			
9.0'		7.9							
11.5'	SC	11.5	25	10	96	47			CLAYEY SAND: reddish brown, moist.
13.0' ▽	CL	21.0							SANDY CLAY: reddish brown, moist.
		20.7	27	11	98	63			wet.
		21.2							
21.0'		16.7							
23.0'	SC				90	19			CLAYEY SAND: reddish brown, wet, gravel to 3 in.
25.0'	SM				65	29			SILTY GRAVELLY SAND: brown, wet, gravel to 3 in., encountered large rock at 26 ft.

EL 520 DEPTH	LOG
1.5'	ML
3.5'	CL
6.5' ▽	SM

EL 521 DEPTH	LOG
2.0'	SM
4.0'	SP
8.0'	CL
10.5' ▽ 11.5'	ML
14.5'	CL

EL 561 DEPTH	LOG
3.0'	ML
6.0'	SC-SM
8.0'	CL
9.0'	ML
14.5'	SM
16.5'	ML
17.5'	SM

SAFETY PA

DESCRIPTION

: brown,moist,some chunks of
,gravels and cobbles to 6 in.
of soil.

: brown,moist,dense,chunks of
d,gravels to 1 in.

: brown — grey intermixed,
stiff,few gravel to 1 in.

DESCRIPTION

: brown-grey intermixed,moist.

brown intermixed,very moist.

DESCRIPTION

T: dark brown,moist,some roots.

Y: brown,moist.

EY SAND: tan to brown,moist.

SANDY CLAY: brown,moist,gravels

AVEL: brown,moist,gravels to

SANDY CLAY: brown,moist.

wn,moist,few gravels to ½ in.

DESCRIPTION

T reddish brown,gravels to 1 in.

ND: reddish brown,moist.

Y: reddish brown,moist.

ND: reddish brown,wet,gravel

WELLY SAND: brown,wet,gravel
encountered large rock at 26 ft.

TT87-3

EL 520 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
1.5'	ML	15.5							SANDY SILT: brown,moist,slightly cohesive,some roots.
3.5'	CL								SANDY CLAY: brown with grey blotches.
6.5' ▽	SM	15.3			97	26			SILTY SAND: brownish grey,very moist.

TT87-4

EL 519 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
1.5'	ML	3.7			99	70			SANDY SILT: brown,moist,slightly cohesive.
3.0'	CL	14.8	29	9	97	66	86.5		SANDY CLAY: brown with grey blotches,moist.
7.0' ▽	ML	21.6	26	4	99	52			SANDY SILT: grey with brown blotches. very moist.

TT87-7

EL 521 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
2.0'	SM				69	17			SILTY GRAVELLY SAND: brown,moist,gravels to 2 in.
4.0'	SP								GRAVELLY SAND: light brown,gravel and cobbles to 6 in.
9.0'	CL	17.8	26	9	97	56	101.5		SANDY CLAY: brown,moist,stiff.
10.5' ▽ 11.5'	ML	22.3		NP	99	53			SANDY SILT: dark grey,very moist.
14.5'	CL								SANDY CLAY: brown,very moist.

TT87-8

EL 528 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
1.5'	ML				96	57			SANDY SILT: dark brown,moist.
	CL	8.9					105.7		SANDY CLAY: brown,few gravels to ¾ in.
		10.5	24	8	83	50			GRAVELLY SANDY CLAY: brown,moist,gravels to 2 in.
					99	52			SANDY CLAY: brown,moist,few gravels to ½ in.
13.5'									GRAVELLY SANDY CLAY: brown,moist,gravels to 2 in.

TT87-11

EL 561 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
3.0'	ML								SANDY SILT: dark brown,moist.
6.0'	SC-SM	10.7	23	7	100	17	113.9	10	CLAYEY SAND-SILTY SAND: brown,moist,cohesive, very stiff.
8.0'	CL	3.5			98	74	104.2	25	SANDY CLAY: brown,moist,very stiff.
9.0'	ML							30	SANDY SILT: light brown,moist,slightly cohesive.
14.5'	SM								SILTY SAND: light brown,some gravels and decomposing granite. SILTYGRAVELLY SAND: brown,moist,gravels to 3in.,slightly cohesive.
16.5'	ML								SANDY SILT: grey with rust colored blotches, moist, cohesive.
17.5'	SM							21	SILTY SAND: light brown with dark yellow streaks of fine sand,moist.

NOTES:

1. TEST TRENCHES WERE EXCAVATED WITH A BACKHOE IN JANUARY 1987.
2. TEST HOLES WERE DRILLED WITH A 24-INCH BUCKET AUGER IN JANUARY 1987.
3. SEE PLATE 14 FOR LEGEND AND CLASSIFICATION SYSTEM
4. SEE PLATE 17 FOR TRENCH AND HOLE LOCATIONS.

SCALE: 1 IN = 5 FT

SCALE 5 0 5 10 15 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE

REVISIONS

U. S. ARMY ENGINEER DIST
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FOUNDATION SOIL LOGS
DIKE AT CORONA SEWAGE TREATMENT P
T.T.87-1 THRU T.T.87-11
T.H.87-1,T.H87-2

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____-B-____

DISTRICT FILE NO.

CHIEF ________ BRANCH

2

TH87-3

EL.531 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
	CL	5.1			97	61			SANDY CLAY: reddish brown, damp, well cemented clods.
		6.1							
			24	9	99	69		24	
		7.4							
		8.6			100	50		19	
									few subrounded gravels to 1 in.
16.0'		9.6							brown.
18.0'	SM				69	30		7	SILTY GRAVELLY SAND: brown, wet.
					80	33			GRAVELLY SILTY SAND: brown, wet, subrounded gravels to 1.5 in.
									subangular gravels to 2in.
					81	19		13	
26.0'								25	
29.0'	SW-SC				77	11		74	GRAVELLY SAND-CLAYEY GRAVELLY SAND: brown, wet, gravels to 1.5 in.
31.0'	SW-SM				74	9		R	GRAVELLY SAND-SILTY GRAVELLY SAND: brown, wet, gravels to 2in.
	SM				82	26			SILTY GRAVELLY SAND: brown with red streaks.
33.0'								R	gravels to 3 in., few cobbles to 5 in.
34.0'	SP-SM				64	8			GRAVELLY SAND-SILTY GRAVELLY SAND: brown, wet, gravels to 2 in.
35.0'	SM								SILTY SAND: brown, wet.
37.0'	SP-SM				82	6		R	GRAVELLY SAND-SILTY GRAVELLY SAND: brown, wet, few cobbles to 5 in.
	SP				55	3			GRAVELLY SAND: brown, wet, subrounded gravel to 3 in.
42.0'									
46.0'	SC-SM		24	6	91	14			CLAYEY SAND-SILTY SAND: brown, wet, gravels to to 2 in.
	SW-SC								SAND-CLAYEY SAND: brown, wet, few cobbles to 6 in.
50.0'									no cobbles.
52.0'	SC				74	23			CLAYEY GRAVELLY SAND: light brown, wet, gravels to 3 in., some cohesion.
54.0'	ML				94	53			SANDY SILT: light brown, wet, lense of silty material.
	SM								SILTY SAND: light brown, wet, gravel to 2 in., lense of silt.
60.0'									brown.

TH87-4

EL.524 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	
	SM				74	27			GRAVELLY SILT gravel to 2 i
		7.6						12	moist.
		10.1							dark brown, da
7.0'		4.3							
	SC								CLAYEY SAND:
11.0'								16	
14.0'	CL								SANDY CLAY: r
	SC	13.5			97	46			CLAYEY SAND:
								17	5% subangular
									gravel to 1 i
21.0'									
23.0'	CL				97	55		26	SANDY CLAY: b
25.0'	SC		32	12	84	42			GRAVELLY CLAY
	SW-SC				60	11			CLAYEY SAND: GRAVELLY SAND w/ black grav 3 in., cobbles
30.0'									
	SP-SC				56	7			GRAVELLY SAND colored, wet, g
34.0'									
35.0'	CL		36	12	98	63			SANDY CLAY: g wet.
	SM				82	22			GRAVELLY SILT wet, gravel to
41.0'					91	49			SILTY SAND: m cobbles to 4
44.0'	GP-GM				36	5			SANDY GRAVEL- colored, wet, c
	SW-SM				78	10			GRAVELLY SAND- colored with lenses of gra
51.0'									encountered l

TH87-6

EL.518 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	DESCRIPTION
	SM	1.8							SILTY SAND: dark brown, moist.
3.0'		11.4	19	2	88	28			light brown, damp.
	CL-ML	6.2	22	5	97	61			SANDY CLAY-SANDY SILT: dark brown, moist.
		7.5							reddish brown.
7.0' 8.0'			21	5	98	62		3	dark brown
	CL	10.3							SANDY CLAY: brown, wet.
12.5'									reddish brown.
	SC	14.3	26	9	100	45	117.5	7	CLAYEY SAND: reddish brown, wet
16.5'									5% gravel to 3/4 in.
19.5'	SM				61	13			SILTY GRAVELLY SAND: multicolored, wet, few cobbles to 5 in.
	GP								SANDY GRAVEL: multicolored, wet, subrounded gravel to 1 in.
					51	4			gravel to 3 in.
30.0'									occasional pockets (3 in.dia.) of greyish greyish brown CL.

TH87-10

EL.540 DEPTH	LOG	MC	LL	PI	-4	-200	γd	N	
3.0'	CL-ML		27	7	98	72			SANDY CLAY-S gravel to 2
	SM	5.6			78	24			GRAVELLY SIL
									gravel to 3
12.0'									
14.5'	GP-GM				52	7			SANDY GRAVEL- slightly dam
	GW-GM	3.7			42	7			SANDY GRAVEL- damp, gravel
20.0'									light brown,
	SP-SM	3.9			74	5			GRAVELLY SAN brown, damp, g
					59	8			some cobbles
									less gravel,
33.0'									end of hole.

G PAY

TION
brown, damp, subangul
m, damp.
rown, wet.
brown, wet.
to 3/4 in.
grey with red, wet
t, few cobbles to 4
GRAVELLY SAND: brown
ubrounded gravel to
GRAVELLY SAND: multi
? in.
rown with red streak
muticolored with gre
enses of grey silt.
red with grey, wet.
NDY GRAVEL: multi-
o 4 in.
RAVELLY SAND: multi-
, gravel to 2 in.,
k.

PTION
: brown, dry to damp.
brown, slightly damp.
es to 5 in
NDY GRAVEL: brown,
NDY GRAVEL: brown,
cobbles to 5 in.
el.
AVELLY SAND light
in.
9 in.

TH 87-4

LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
SM				74	27			GRAVELLY SILTY SAND: brown, damp, subangular gravel to 2 in.
	7.8						12	moist.
	10.1							dark brown, damp.
	4.3							
SC							16	CLAYEY SAND: dark brown, damp.
CL								SANDY CLAY: reddish brown, wet.
SC	13.5			97	46		17	CLAYEY SAND: reddish brown, wet.
								5% subangular gravel to 3/4 in.
								gravel to 1 in.
CL				97	55		26	SANDY CLAY: brown, wet.
SC		32	12	84	42			GRAVELLY CLAYEY SAND: grey with red, wet.
								CLAYEY SAND: brown, wet, few cobbles to 4 in.
SW-SC				60	11			GRAVELLY SAND-CLAYEY GRAVELLY SAND: brown w/ black gravel, wet, subrounded gravel to 3 in., cobbles to 4 in.
SP-SC				56	7			GRAVELLY SAND-CLAYEY GRAVELLY SAND: multicolored, wet, gravel to ? in.
CL		38	12	98	63			SANDY CLAY: greyish brown with red streaks, wet.
SM				82	22			GRAVELLY SILTY SAND: muticolored with grey, wet, gravel to 1 in., lenses of grey silt.
				91	49			SILTY SAND: multicolored with grey, wet, cobbles to 4 in.
GP-GM				56	5			SANDY GRAVEL-SILTY SANDY GRAVEL: multicolored, wet, cobbles to 4 in.
SW-SM				78	10			GRAVELLY SAND-SILTY GRAVELLY SAND: multicolored with grey, wet, gravel to 2 in., lenses of grey silt.
								encountered large rock.

TH 87-5

EL.518 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	SM	4.0							SILTY SAND: dark brown, damp.
3.0'		6.0							reddish brown.
	CL	0.7	23	8	98	57		28	SANDY CLAY: reddish brown, damp.
									few gravel to 3/4 in.
8.5'									
▽10.0'	CL	10.1							SANDY CLAY: brown, wet.
		12.4							
		15.2						13	reddish brown.
15.0'									
	SC				89	34			CLAYEY SAND: reddish brown, wet, subrounded gravel to 3/4 in.
20.0'								8	coarse fraction is muticolored.
	GP-GM				50	6			SANDY GRAVEL-SILTY SANDY GRAVEL: multicolored and reddish-brown, wet, cobbles to 5 in.
									Subrounded cobbles to 4 in.
27.0'									encountered large rock.

TH 87-12

EL.552 DEPTH	LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
	CL	7.3			100	77			SANDY CLAY: reddish brown, damp, stiff.
		9.2							
		14.2	42	26	100	72			damp to moist, hard.
10.0'		19.2							reddish and yellowish brown, very hard.
	SP-SC	4.9							GRAVELLY SAND-CLAYEY GRAVELLY SAND: yellowish red-brown.
14.0'		4.4							reddish brown, gravel to 2 in.
									yellowish brown, gravel to 3 in.
15.0'	SC	13.2	25	9	97	34			CLAYEY SAND: yellowish and reddish brown, moist.
16.0'	SM	9.8							SILTY SAND: yellowish brown, damp, caving at 15 ft.
18.0'	SP	4.5							GRAVELLY SAND: yellowish brown, damp, loose, some gravel to 3 in.
20.0'	CL	88.5			97	80			SANDY CLAY: yellowish brown, moist, hard, plastic.
	SP-SM				75	5			GRAVELLY SAND-SILTY GRAVELLY SAND: yellowish brown, damp, loose.
									few cobbles, caving at 25 ft.
30.0'									damp to moist.

TH 87-10

LOG	MC	LL	PI	-4	-200	γ_d	N	DESCRIPTION
CL-ML		27	7	98	72			SANDY CLAY-SANDY SILT: br dry to damp, gravel to 2 in.
SM	5.6			78	24			GRAVELLY SILTY SAND: brown, slightly damp.
								gravel to 3 in., cobbles to 5 in.
GP-GM				52	7			SANDY GRAVEL-SILTY SANDY GRAVEL: brown, slightly damp.
GW-GM	3.7			42	7			SANDY GRAVEL-SILTY SANDY GRAVEL: brown, damp, gravel to 3 in., cobbles to 5 in.
								light brown, less gravel.
SP-SM	3.9			74	5			GRAVELLY SAND-SILTY GRAVELLY SAND: light brown, damp, gravel to 3 in.
				59	8			some cobbles to 5 in.
								less gravel, cobbles to 9 in.
								end of hole.

NOTES:

1. TEST HOLES WERE DRILLED WITH A 24"-INCH BUCKET AUGER IN JANUARY 1987.
2. SEE PLATE 36 FOR LEGEND AND CLASSIFICATION SYSTEM.
3. SEE PLATE 77 FOR TEST HOLE LOCATIONS.

SCALE: 1 IN.= 5 FT.
5 0 5 10 15

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE

REVISIONS

U. S. ARMY ENGINEER DI
LOS ANGELES
CORPS OF ENGINEER

DESIGNED BY:
DRAWN BY:
CHECKED BY:

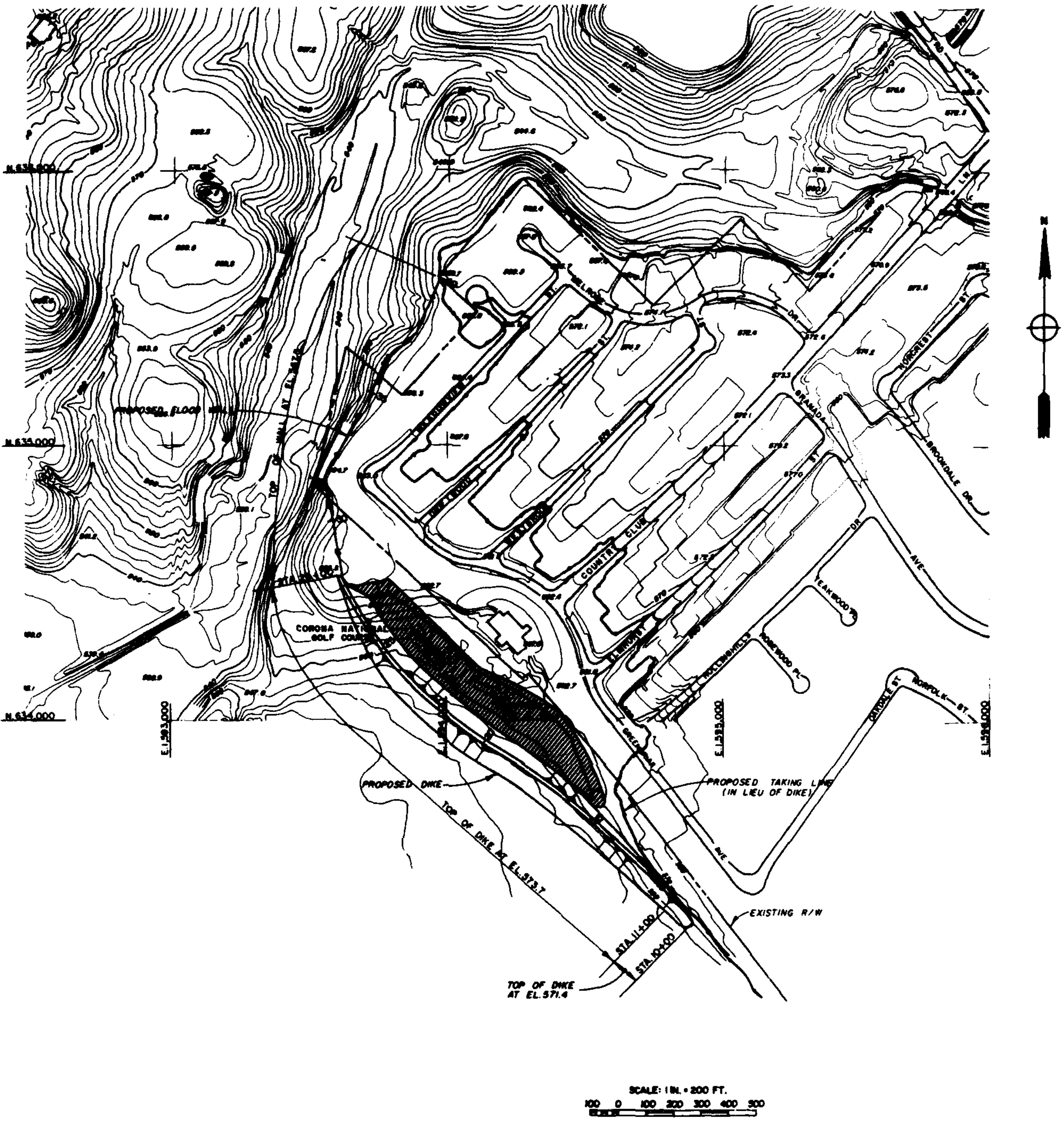
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FOUNDATION SOIL LOGS
DIKE AT CORONA SEWAGE TREATMENT
T.H.87-3 THRU T.H.87-6
T.H.87-10, T.H.87-12

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09- ___ B- _
DISTRICT FILE NO.

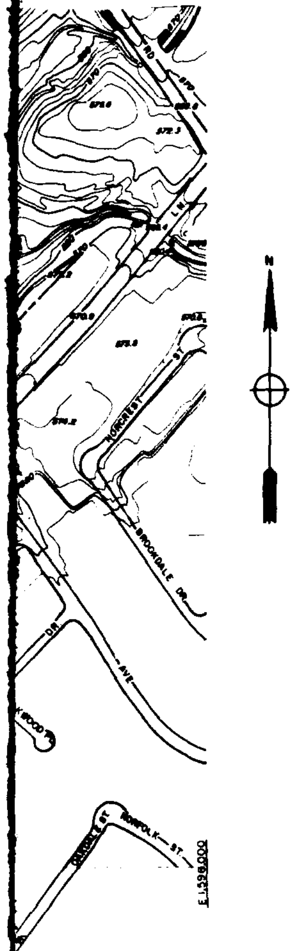
VALUE ENGINEERI



SAFETY PA

PAYS

VALUE ENGINEERING PAYS



DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	AP

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

DIKE AT CORONA NATIONAL HOUSING TR
PLAN AND TYPICAL CROSS SECTION

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

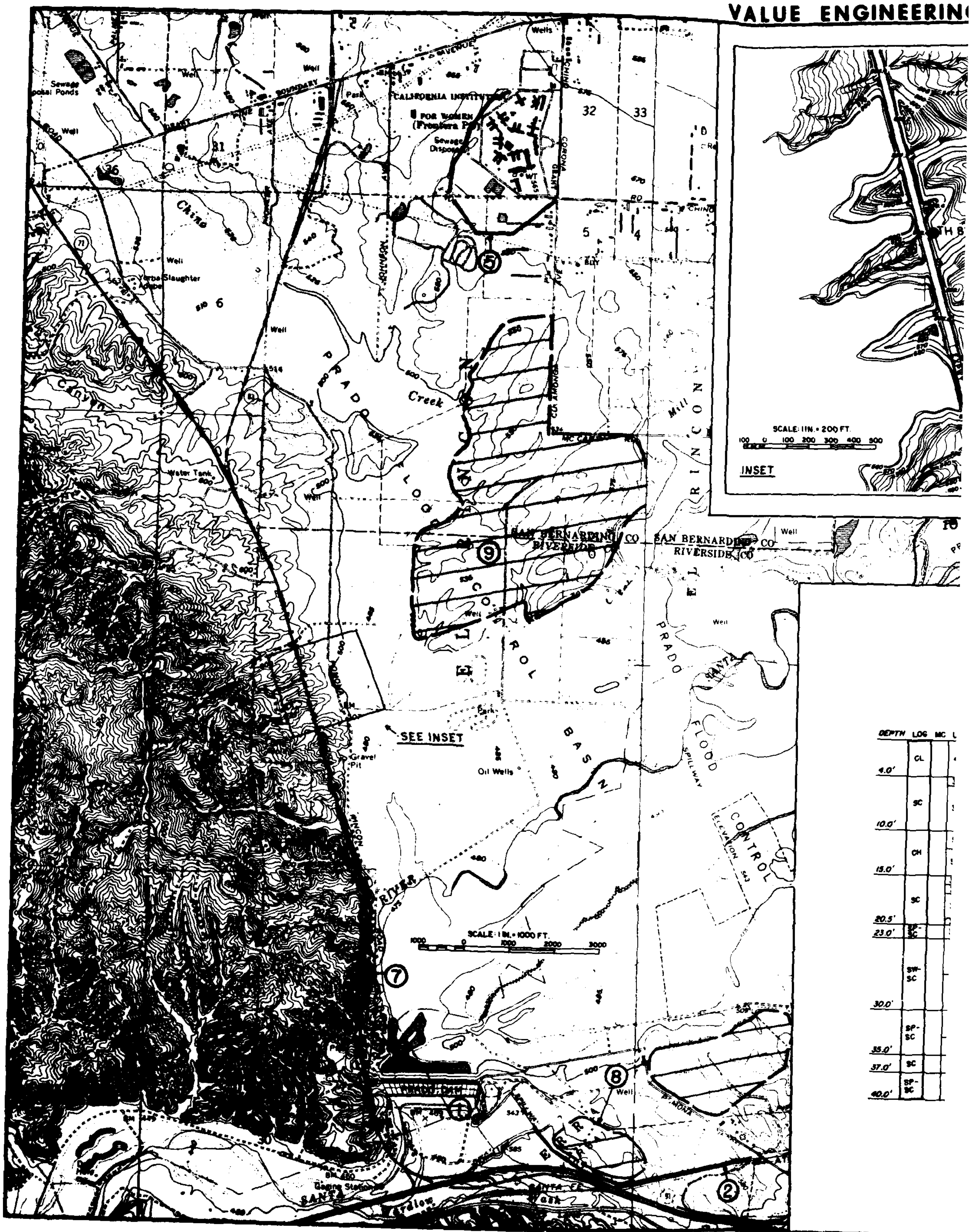
PLA

SAFETY PAYS

1

2

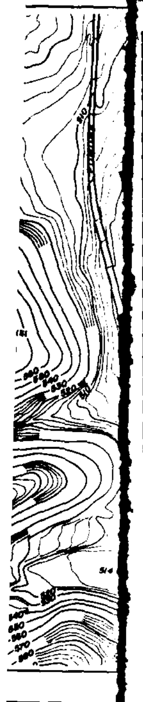
VALUE ENGINEERIN

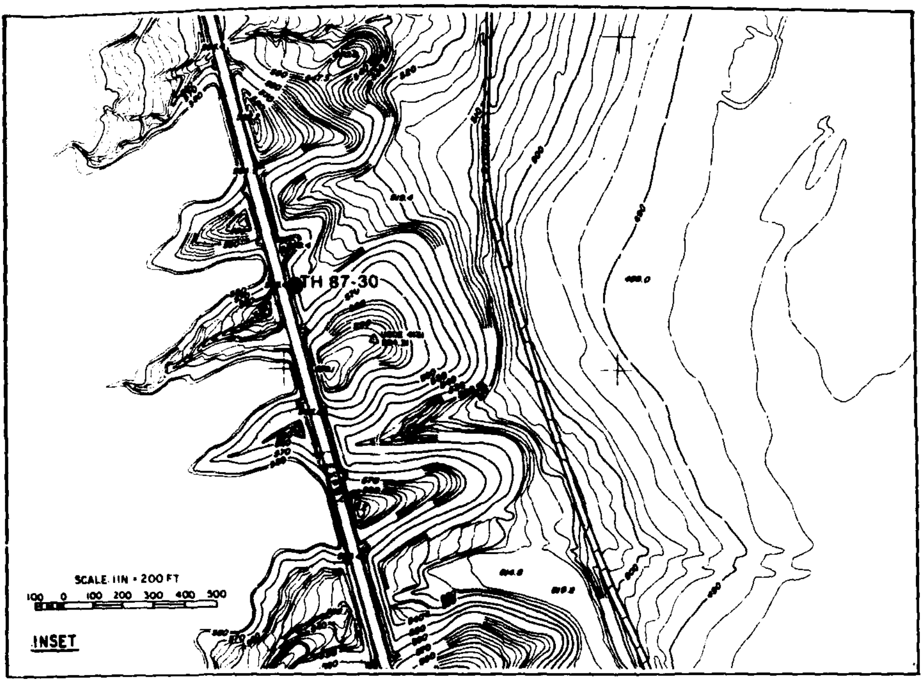


SAFETY PA

1

AYS





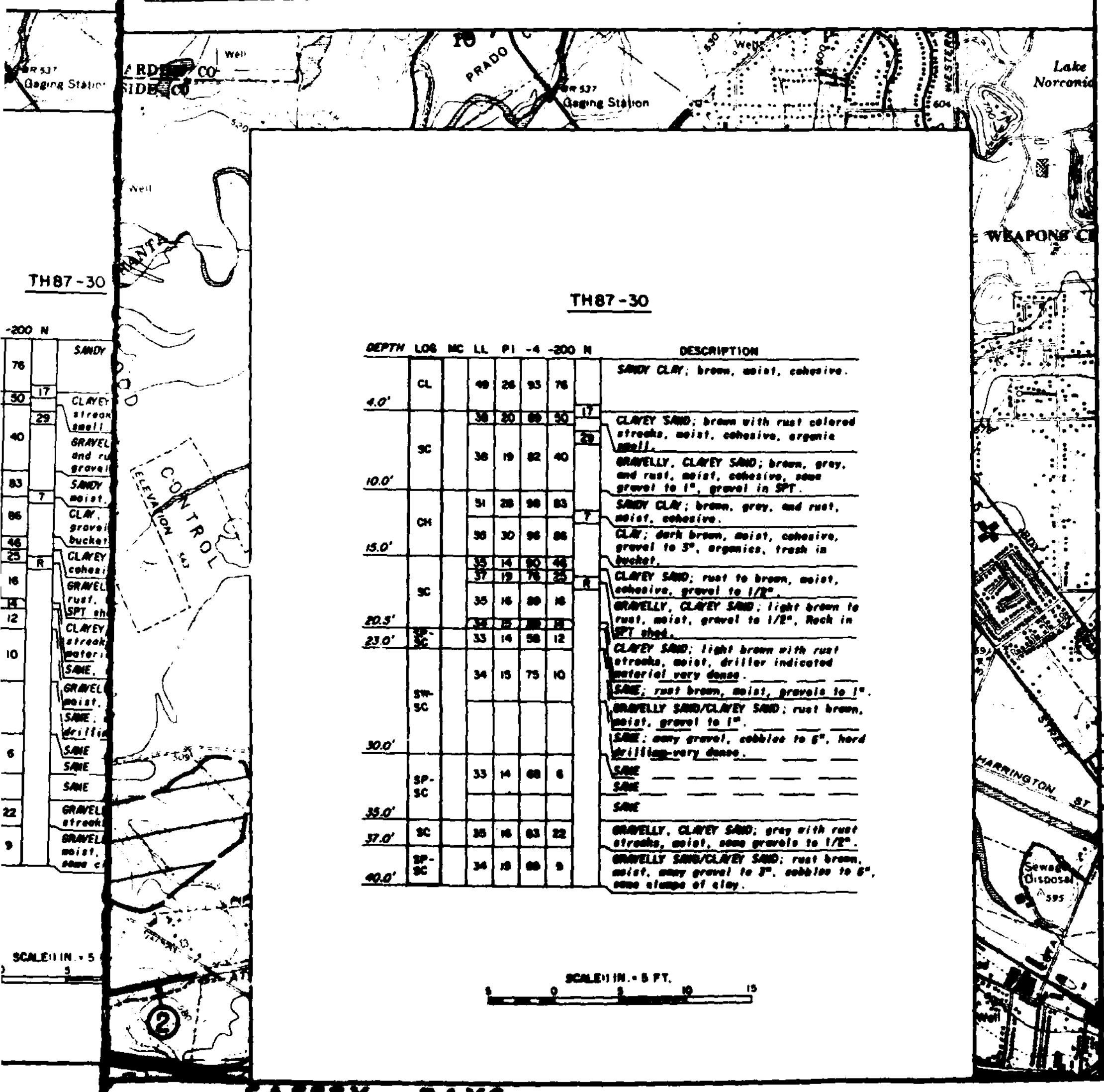
PRADO BASIN

①	PRADO DAM
②	AUXILIARY DIKE
★③	DIKE AT CORONA SEWAGE TREATMENT PLANT
★④	DIKE AT ALCOA ALUMINUM PLANT
⑤	DIKE AT CALIFORNIA INSTITUTION FOR WOMEN
★⑥	DIKE AT CORONA NATIONAL HOUSING TRACT
⑦	DIKE AT CORONA EXPRESSWAY
⑧	BORROW AREA NO.1
⑨	BORROW AREA NO.2

★ 3,4,AND 6 NOT SHOWN

NOTES:

1. SEE PLATE [illegible] FOR LEGEND AND CLASSIFICATION SYSTEM
2. TEST HOLES WERE DRILLED USING A 24" BUCKET AUGER IN APRIL 1987.
3. THE LOG OF THAT HOLE INDICATES THE GEOTECHNICAL CONDITIONS AT THAT LOCATION AT THAT PARTICULAR TIME. SOIL CONDITIONS CAN CHANGE WITH TIME. THE STRATIFICATION LINES SHOWN ON THE LOGS REPRESENT THE APPROXIMATE BOUNDRY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL OR ABRUPT



TH87 - 30
SCALE:1 IN. = 5

TH87 - 30

DEPTH	LOG	MC	LL	PI	-4	-200	N	DESCRIPTION
4.0'	CL		49	28	93	76		SANDY CLAY; brown, moist, cohesive.
	SC		38	20	89	50	17	CLAYEY SAND; brown with rust colored streaks, moist, cohesive, organic smell.
10.0'			38	19	82	40	29	GRAVELLY, CLAYEY SAND; brown, grey, and rust, moist, cohesive, some gravel to 1", gravel in SPT.
	CH		51	28	98	83	7	SANDY CLAY; brown, grey, and rust, moist, cohesive.
15.0'			38	30	96	86		CLAY; dark brown, moist, cohesive, gravel to 3", organics, trash in bucket.
	SC		35	14	90	46		
			37	19	76	25	R	CLAYEY SAND; rust to brown, moist, cohesive, gravel to 1/2".
			35	16	80	16		GRAVELLY, CLAYEY SAND; light brown to rust, moist, gravel to 1/2", Rock in SPT shoe.
20.5'			38	15	[illegible]	18		
23.0'	SP-SC		33	14	58	12		CLAYEY SAND; light brown with rust streaks, moist, driller indicated material very dense.
	SW-SC		34	15	75	10		SAME; rust brown, moist, gravels to 1".
30.0'								GRAVELLY SAND/CLAYEY SAND; rust brown, moist, gravel to 1". SAME; many gravel, cobbles to 6", hard drilling-very dense.
	SP-SC		33	14	68	6		SAME SAME
35.0'								SAME
37.0'	SC		35	16	83	22		GRAVELLY, CLAYEY SAND; grey with rust streaks, moist, some gravels to 1/2".
40.0'	SP-SC		34	15	89	9		GRAVELLY SAND/CLAYEY SAND; rust brown, moist, many gravel to 3", cobbles to 6", some clumps of clay.

SCALE:1 IN. = 5 FT.
5 0 5 10 15

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
LOCATION AND SOIL LOG
DIKE AT CORONA EXPRESSWAY
TH-87-30

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09- ____ B- ____
DISTRICT FILE NO.
SHEET

PLATE 8

VALUE ENGINEERING PA

Cont. No.

Date *March 1949*

Contractor *Preliminary*

Res. Engr.

STANDARD SOIL SURVEY SHEET

From Route 43 to Pine Avenue.

Boring & Sample No.	TH #1	TH #3	TH #5		1	2	3	4	5	6	7	8	9	10	11
Date Sampled	12-30-48	12-30-48	12-30-48		3-29-48	9-22-48	9-27-48	2-21-49	9-29-48	1-29-48	2-21-49	2-21-49	1-29-48	2-21-49	1-29-48
Dist. or Cen. Lab. Test No.	VIII-651	VIII-552	VIII-561		48-4472	48-4465	48-4466	6	48-4467	VIII-196	7	8	VIII-196	9	VIII-196
Station	TH #1	TH #5	TH #5		91+65	91+75	93+50	100+00	103+60	108+50	109+00	121+00	121+50	143+00	146+00
Depth	0'-6'	3'-15'	0'-15'		Stockpile	Stockpile	Top 2'	Top 3'	[illegible]	Top 2'	6" to 3'	Top 3'	Top 2'	6" to 3'	Top 2'
Mechanical analysis	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]		[illegible]	[illegible]			[illegible]		[illegible]
Liquid limit							20			19			20		20
Plasticity index	N.P.	N.P.	N.P.		N.P.	N.P.	2		N.P.	0			2		4
R-Resistance value	C-85	C-83+	C-80		C-79	S-80	C-40		C-80+	C-43			C-50		C-48
Recommended thickness	2"	2"	2"		2"	2"	13"		2"	13"			11"		12"
Cohesiometer value	149	285				93									
Remarks	*Proposed Source Selected Material*														

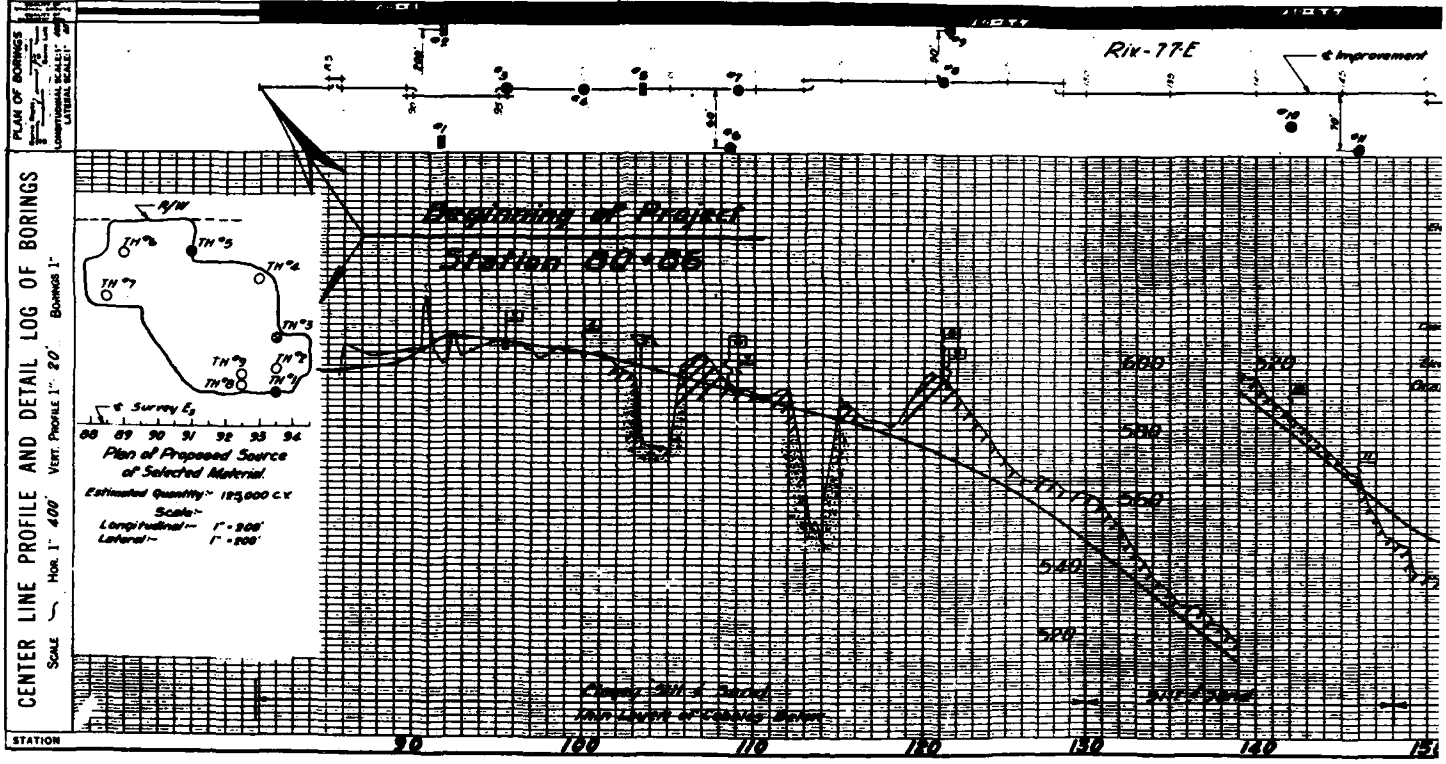
LEGEND

OGS	Original Ground Surface	AC	Asphalt Concrete Pavement	St	Silt (y)
BS	Basement Soil	PCC	Portland Cement Concrete Pav't.	Cl	Clay (ey)
SB	Subbase	PMS	Plant-mixed Surfacing	Sd	Sand (y)
IBM	Imported Base Material	BST	Bituminous Surfacing Treated	Sh	Shale
SM	Selected Material	URB	Untreated Rock Base	Ss	Sandstone
IB	Imported Borrow	CTB	Cement Treated Base	Gv	Gravel

1" Soil Sample · Auger Boring · 2" Power Boring · Trench or Bank · Plan of any type of boring.

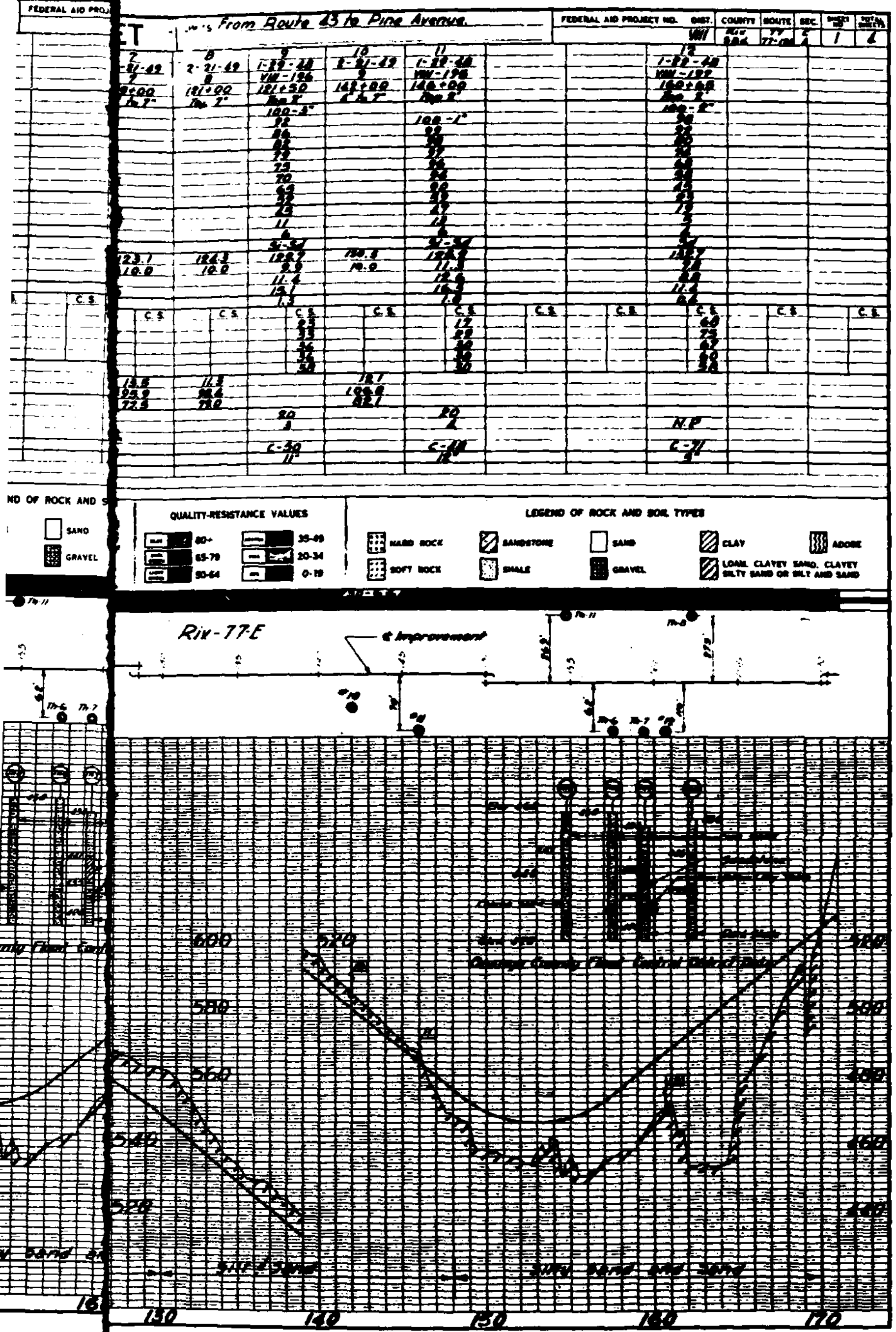
QUALITY-RESISTANCE VALUES: 80+ · 65-79 · 50-64 · 35-49 · 20-34 · 0-19

▦ HARD ROCK · ▦ SOFT ROCK



SAFETY PAYS

LUE ENGINEERING PAYS



FEDERAL AID PROJ

ET … From Route 43 to Pine Avenue.

FEDERAL AID PROJECT NO.	DIST.	COUNTY	ROUTE	SEC.	SHEET NO.	TOTAL SHEETS
	VIII	Riv SBd	77 77-192	E A	1	6

7	8	9	10	11	12
-21-49	2-21-49	1-29-48	2-21-49	1-29-48	1-29-48
7	8	VIII-196	9	VIII-196	VIII-199
+00	121+00	121+50	142+00	146+00	160+68
To 2'	Top 2'	Top 2'	2' to 7'	Top 2'	Top 2'
		100-3"			100-2"
		92		100-1"	98
		86		99	92
		82		98	80
		79		97	76
		75		96	66
		70		94	58
		62		90	45
		52		88	23
		29		47	13
		11		18	5
		6		6	4
		51-54		51-54	51-54
123.1	124.3	128.7	130.8	128.8	125.7
10.0	10.0	9.9	10.0	11.5	7.8
		11.4		12.6	8.8
		15.1		16.3	11.4
		1.3		1.8	0.4
C.S.	C.S.	C.S.	C.S.	C.S.	C.S.
		25		17	60
		33		22	73
		34		30	67
		36		30	60
		38		30	58
13.5	11.3		12.7		
95.9	98.4		106.8		
77.5	78.0		82.1		
		20		20	N.P.
		3		4	
		C-50		C-48	C-71
		11"		12	5"

ND OF ROCK AND S

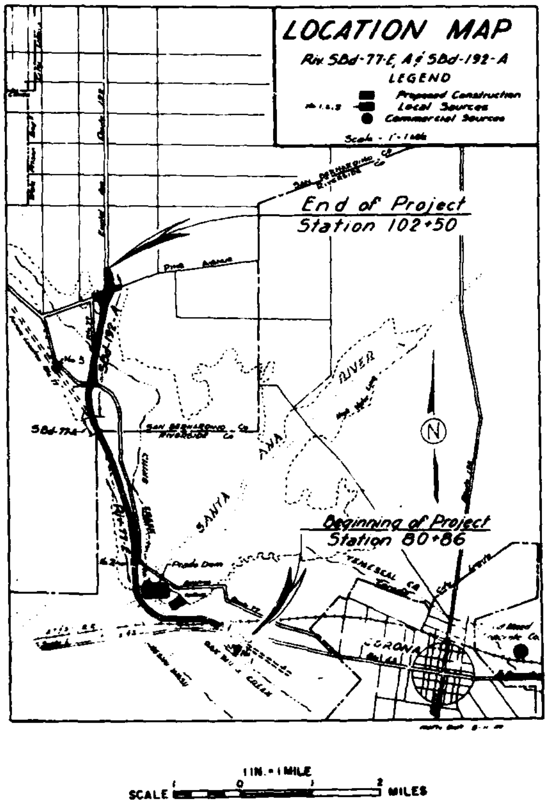
- ☐ SAND
- ▦ GRAVEL

QUALITY-RESISTANCE VALUES

80+	35-49
65-79	20-34
50-64	0-19

LEGEND OF ROCK AND SOIL TYPES

- ▦ HARD ROCK
- ▨ SANDSTONE
- ☐ SAND
- ▨ CLAY
- ▦ ADOBE
- ▦ SOFT ROCK
- ▦ SHALE
- ▦ GRAVEL
- ▨ LOAM, CLAYEY SAND, CLAYEY SILTY SAND OR SILT AND SAND



NOTE:

1 LOCATION PLAN AND LOGS OF BORINGS WERE RECEIVED FROM CALTRANS

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
LOCATION MAP
SOIL LOGS BY OTHERS
CORONA EXPRESSWAY
REACH RIV.-77-E

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____-B-____

DISTRICT FILE NO.

SHEET

PLATE B-79

SAFETY PAYS

1

2

Cont. No. ______ Date *March 1949*

Contractor *Preliminary*
Res. Eng'r.

STANDARD SOIL SURVEY SHEET

Limits *From Route 43 to P*

Boring & Sample No.	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30A	30B	31
Date Sampled	9-30-48	9-30-48	1-29-49	1-29-49	3-8-49	1-19-49	5-8-41	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lab. Test No.	48-4469	48-4470	VW-128	VW-124	49-1298	4	39273	[illegible]	[illegible]	[illegible]	[illegible]	11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Station	173+00	173+75	176+27	176+43	178+50	178+50	182+00	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Depth	3d Outcrop	15' Bank	Top 2'	20' Bank	15' Bank	Top 7'	4'-8'	Top 2'	[illegible]	Top 5'	[illegible]	[illegible]	Top 5'	[illegible]	Top 5'	Top 5'	5' Bank	Top 5'	5'-8'	[illegible]
Mechanical Analysis, Total % Passing	100-3/4" 97 96 93 88 60 30 16 2 1	100 99 98 94 82 47 41 12 5	100 98 94 67 58 50 19 10	100 97 82 55 18 15 4 2	100 94 91 87 84 67 59 16 6		100 91 83 73 62 49 30 23 11 5	100-1" 94 88 77 78 68 54 41 19 16 5 1	100-3/4" 98 94 68 93 46 38 25 10 8 2 1	100 96 83 78 63 45 27 8 7 4 1	100 97 88 67 53 38 13 9 2 -		100-2" 99 96 88 84 80 73 62 26 21 7 3	100 91 78 62 58 44 30 11 8 2 -	100 93 78 65 47 34 13 11 4 3	100 99 98 76 92 81 37 27 9 5	100 89 88 44 37 30 22 8 6 3 1	100 98 85 88 18 9 1 1	100 98 92 77 69 26 5 3	100 99 97 86 58 19 16 2 -
Description of Soil	Sd	Si-Sd	Si-Sd	Sd	Si-Sd	Sd	Si-Sd	Sd	Sd	Sd	Sd		Sd	Sd	Sd	Sd	Sd	Sd	Sd	Sd
Density lb. cu. ft. Comp.	116.2	122.6	122.2	120.4	120.0	122.1	122.4	122.7	131.2	130.1	126.8	122.0	130.1	122.7	130.7	116.6	124.0	110.1	125.7	108.8
Moisture % of Dry Weight	12.3 13.4 15.0	9.2 12.8 14.9	10.8 12.2 14.3	7.9 11.7 14.2	12.1 18.6 22.3	10.0	8.1 9.6 12.1	7.6 8.3 10.3	6.7 7.7	6.2 8.6 9.4	9.0 9.9 11.2	7.0	9.1 9.7 11.3	6.5 9.4	7.1 9.5	10.9 13.6 20.0	6.9 8.3 11.3	9.4 13.6 16.8	9.0 10.1 17.1	13.0 14.8 15.5
Expansion %	0.4	1.8	2.1	0.3	9.0		1.3	0.5	0.1	0.2	0.1		0.5	0.6	0.4	2.8	0.1	0.5	2.6	0.1
Bearing Ratio Test, Percent of Standard	C.S. 61 48 39 36 33	C.S. 58 57 48 36 35	C.S. 10 14 12 18 19	C.S. 95 82 64 55 55	C.S. 3 3 4 4 4	C.S.	C.S. 46 57 56 55 55	C.S. 135+ 120+ 105+ 90+ 75+	C.S. 118 91 69 57 55	C.S. 155 120+ 105+ 90+ 75+	C.S. 92 68 51 46 45		C.S. 88 114 105+ 90+ 75+	C.S. 105 79 68 56 63	C.S. 75 69 67 64 62	C.S. 6 16 18 17 17	C.S. 196+ 120+ 105+ 90+ 75+	C.S. 48 44 38 34 30	C.S. 20 28 33 31 30	C.S. 46 22 18 17 18
Soil in Place: Moisture % / Dry Weight / Relative Compaction						10.9 120.5 97.8						5.5 120.0 98.3				18.2 98.6 86.3				
Liquid Limit		25			41		29		32		25			21		28				21
Plasticity Index	NP	4	NP	NP	20		12	NP	2	NP	5		NP	1	NP	4	NP	NP	NP	1
R-Resistance Value	C-72	C-54	C-41	C-77	C-16		C-62	C-79	C-79	C-80+	C-78		C-73	C-79	C-75	C-40	C-83	C-70	C-63	C-69
Recommended Thickness	4"	10"	14"	4"	22"		7"	3"	5"	3"	5"		4"	5"	4"	14"	5"	5"	10"	5"
[illegible] Value									245		110			116						

Remarks: *To be disposed of as lower portion of Embankment*

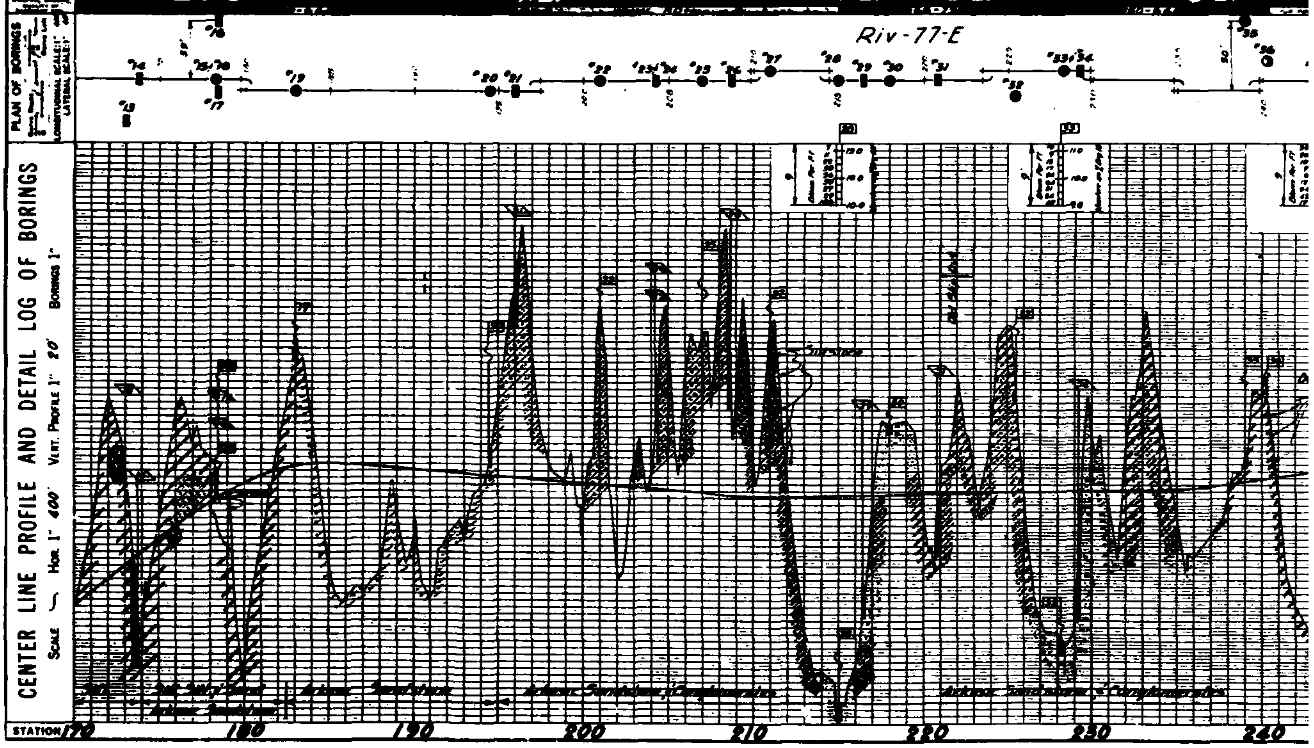
LEGEND					
OGS	Original Ground Surface	AC	Asphalt Concrete Pavement	Si	Silt (y)
BS	Basement Soil	PCC	Portland Cement Concrete Pav't.	Cl	Clay (ey)
SB	Subbase	PMS	Plant-mixed Surfacing	Sd	Sand (y)
IBM	Imported Base Material	BST	Bituminous Surfacing Treated	Sh	Shale
SM	Selected Material	URB	Untreated Rock Base	Ss	Sandstone
IB	Imported Borrow	CTB	Cement Treated Base	Gr	Gravel

1" Soil Sample Auger Borings 2" Power Borings Trench or Bank

○ Plan of any type of boring.

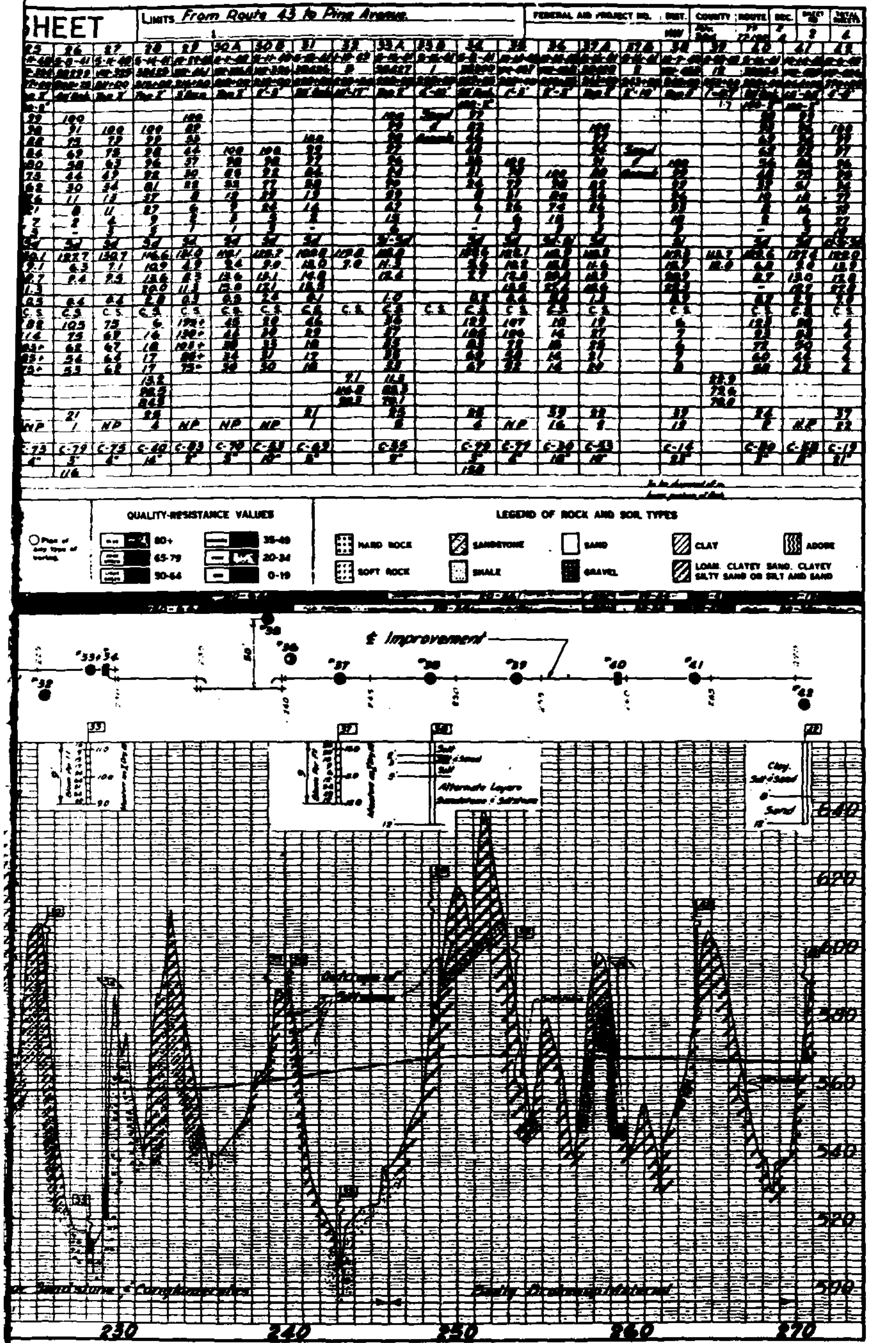
QUALITY-RESISTANCE VALUES

▨ 80+	▨ 35-49
▨ 65-79	▨ 20-34
▨ 50-64	▨ 0-19



1

UE ENGINEERING PAYS



NOTE:

1. LOGS OF BORINGS WERE RECEIVED FROM CALTRANS.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS BY OTHERS
CORONA EXPRESSWAY
REACH RIV.-77-E

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

PLATE B-80

SAFETY PAYS

1

2

Cont. No.
Date *March 1949*

Contractor *Preliminary*
Res. Eng'r

STANDARD SOIL SURVEY SHEET

Limits *From Route 43 to P*

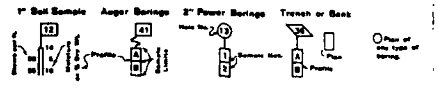
Boring & Sample No.	43	44	45	46	47	48	49	50		51	52
Date Sampled	2-23-49	6-19-41	10-7-48	10-15-48	5-19-41	5-19-41	5-19-41	9-30-48		5-7-41	9-23-48
Dist. or Cen. Lab. Test No.	13	38555	VIII-454	VIII-455	38556	38557	38558	48-4471		38296	48-4468
Station	270+50	271+40	275+50	292+50	295+50	293+75	298+00	306+35		310+20	6+00
Depth	Top 7"	4'-6'	3'-4'	2'-3½'	4'-6'	3'-6'	Top 4'	Top 3'		2'-8' Bank	Top 8'
Mechanical Analysis Total % Passing								100-3"			
1½" Square Openings						100	100	97			
¾"			100	100		99	94	93		100	100
4 Mesh ·4760 Microns			94	98	100	93	89	85		93	99
8 ·2380		100	93	97	98	90	50	80		88	98
16 ·1190		93	88	91	96	86	43	75		81	97
30 ·590		95	86	86	95	83	37	70		74	96
50 ·297		90	83	81	88	78	31	62		67	89
200 ·74		58	52	58	68	53	16	34		46	37
270 ·53		46	44	54	59	50	13	33		39	31
5 Microns		14	7	20	26	18	4	12		18	13
1		5	4	11	10	8	1	6		8	6
Description of Soil		Sl-Sd	Sl-Sd	Cl-Sl-Sd	Cl-Sl-Sd	Cl-Sl-Sd	Sd	Sl-Sd		Cl-Sd	Sl-Sd
Bearing Ratio Test: Density lb. ft.³ Comp.	121.0	116.4	134.2	124.2	122.5	122.5	134.0	129.9		130.4	123.6
Moisture % of Dry Weight: Compacted	8.5	12.7	14.7	13.8	9.6	9.0	6.3	9.0		8.9	8.6
Moisture % of Dry Weight: Soaked		19.9	21.1	16.5	14.8	16.2	7.5	10.1		10.4	12.2
Moisture % of Dry Weight: Average Top 1"		22.5	25.7	17.6	25.1	20.6		14.3		14.9	17.6
Expansion %		0.6	6.8	1.7	3.3	8.7	0.2	1.9		2.2	2.9
Percent of Standard, Pen. 0.1" (C.S.)		3	10	13	2	3	140	28		14	6
0.2"		5	14	14	2	3	119	31		15	11
0.3"		6	16	15	2	4	106	31		16	13
0.4"		6	16	14	3	4	102	30		13	14
0.5"		6	16	14	3	4	102	29		13	16
Soil in Place: Moisture % Dry Weight	18.0										
Dry Weight lb. ft.³	90.0										
Relative Compaction %	74.3										
Liquid Limit		38		29	36	29	22	30		30	27
Plasticity Index		12	NP	12	18	11	4	12		13	8
SE Sand Equivalent											
R Resistance Value		C-19	C-36	C-44	C-11	C-18	C-79	C-52		C-43	C-32
Recommended Thickness		21"	16"	13"	23"	21"	3"	11"		13"	17"

CBR = California Bearing Ratio
C = Compacted
CS = Compacted and Soaked
F = Field Density and Moisture
FS = Field Density and Moisture Soaked 4 Days

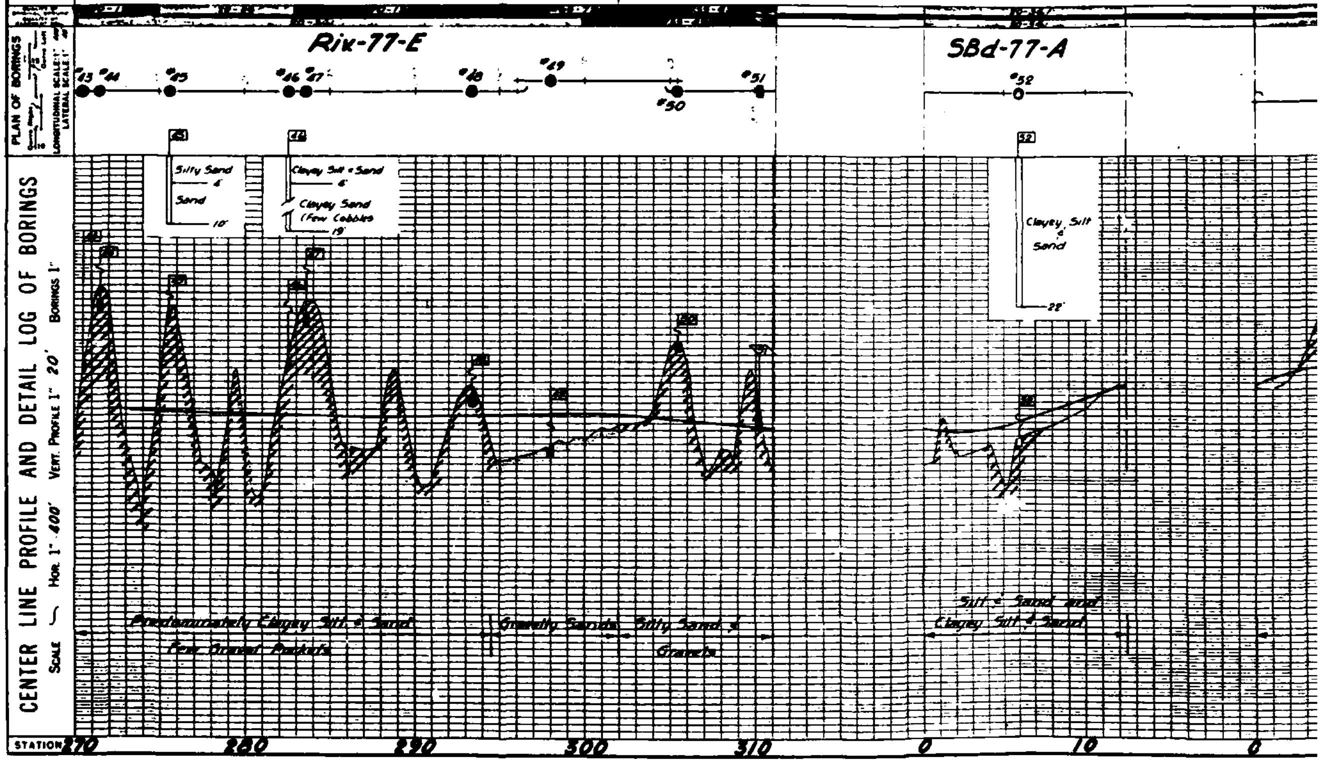
Remarks: *To be disposed of in lower portion of Emb.* — *To be disposed of in lower portion of Embankment*

LEGEND

OGS	Original Ground Surface	AC	Asphalt Concrete Pavement	Si	Silt (y)
BS	Basement Soil	PCC	Portland Cement Concrete Pav't.	Cl	Clay (ey)
SB	Subbase	PMS	Plant-mixed Surfacing	Sd	Sand (y)
IBM	Imported Base Material	BST	Bituminous Surfacing Treated	Sh	Shale
SM	Selected Material	URB	Untreated Rock Base	Ss	Sandstone
IB	Imported Borrow	CTB	Cement Treated Base	Grv	Gravel

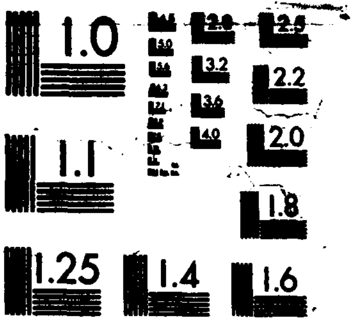


QUALITY-RESISTANCE VALUES
80+
65-79
50-64
35-49
20-34
0-19



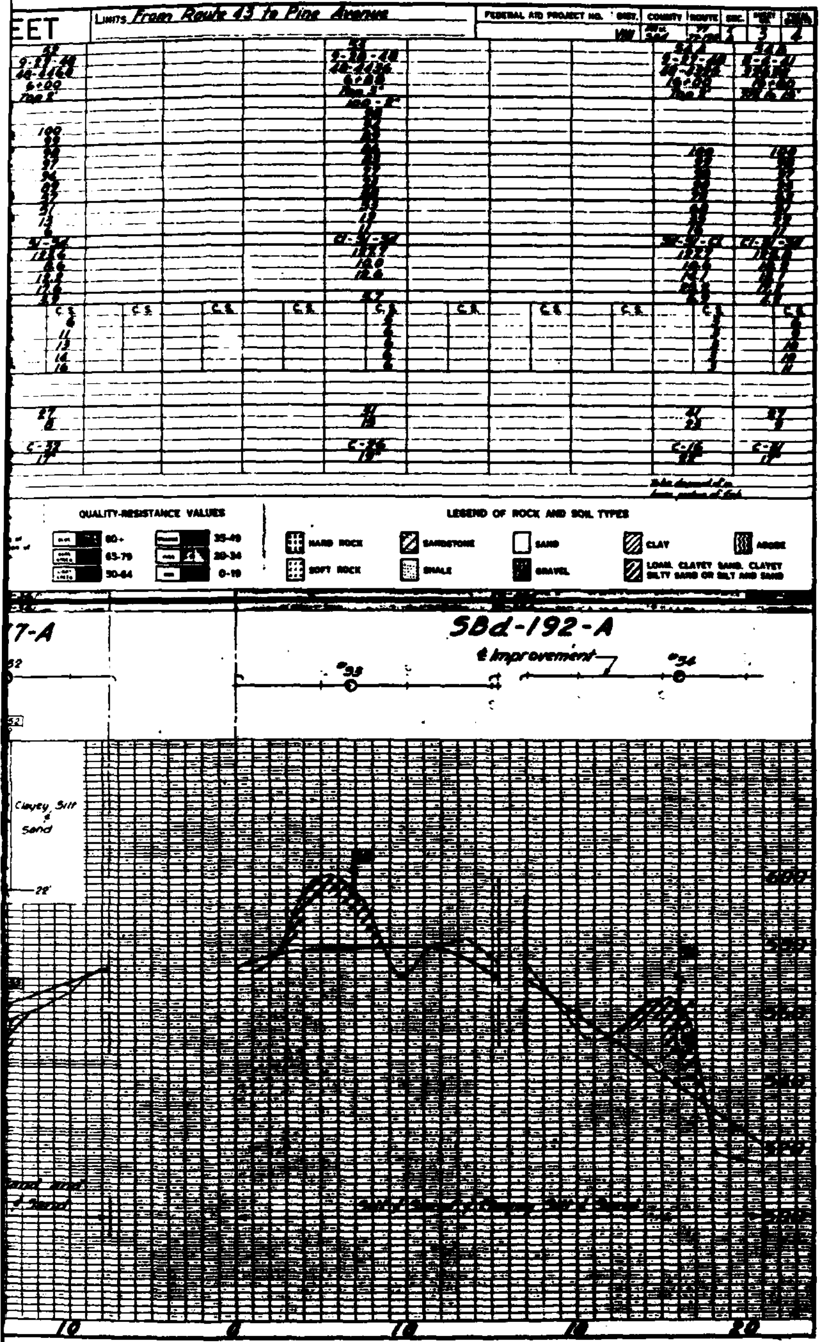
AD-A204 542 SANTA ANA RIVER DESIGN MEMORANDUM NUMBER 1 PHASE 2 GDM ON THE SANTA ANA R..(U) ARMY ENGINEER DISTRICT LOS ANGELES CA AUG 88 6/10

UNCLASSIFIED F/G 13/2 NL



MICROC

E ENGINEERING PAYS



NOTE:

1. LOGS OF BORINGS WERE RECEIVED FROM CALTRANS

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SOIL LOGS BY OTHERS
CORONA EXPRESSWAY
REACH RIV.-77-E, SBD-77-A, SBD-192-A

SPEC. NO. DACW09-____ B-____

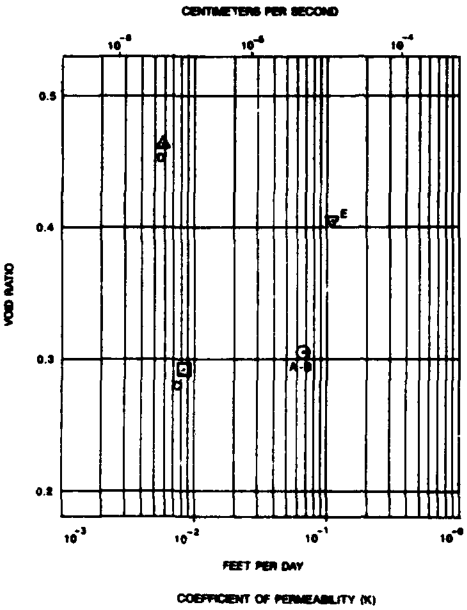
DISTRICT FILE NO.

PLATE B-61

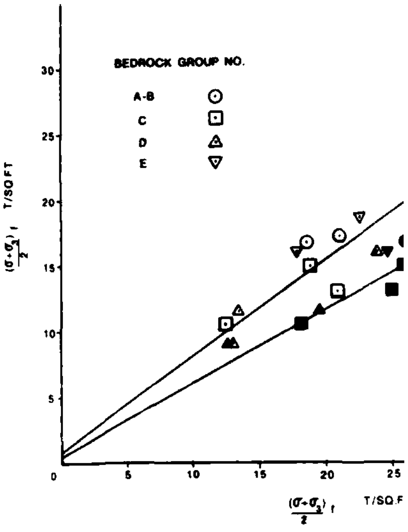
2

SAFETY PAYS

VALUE ENGINEERING

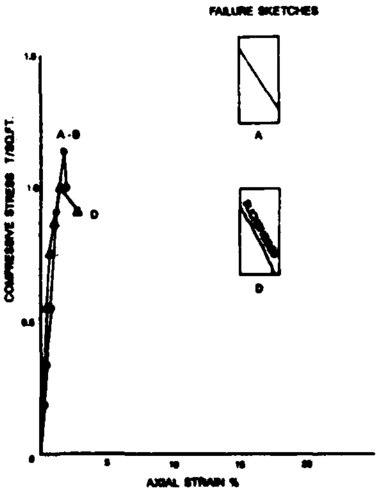


PERMEABILITY

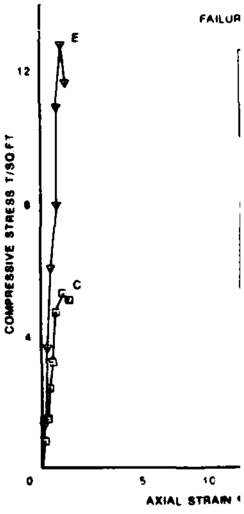


CONSOLIDATED UNDRAINED

p-q PLOTS

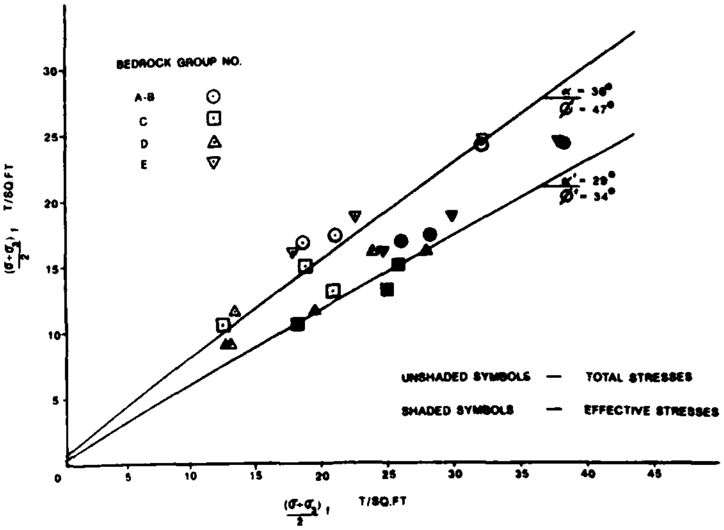


UNCONFINED COMPRESSION



UNCONFINED CO

SAFETY PAYS

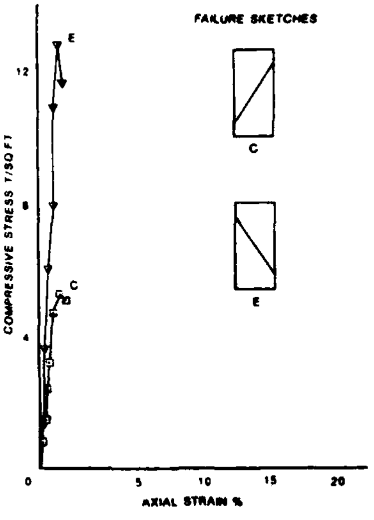


CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION

p-q PLOTS

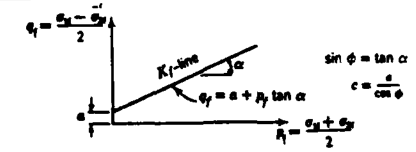
LEGEND

BEDROCK GROUP	SYMBOL	HOLE No.	DEPTH (FT)	USCS	TEST
A-B	⊙	R83-3	137.5 – 138.3	SM	UC
		R83-9	65.0 – 66.0	SC	CU
		R83-3	66.0 – 66.8	SM	CU
		R83-3	99.5 – 100.3	SM	CU
C	⊡	R83-18	126.5 – 127.3	ML	UC
		R83-1	88.9 – 91.1	SM	CU
		R83-16	53.5 – 54.6	SM	CU
		R83-16	95.5 – 96.9	ML	CU
D	△	R83-7	56.2 – 56.3	CL	UC
		R83-7	37.2 – 37.2	ML	CU
		R83-7	36.0 – 36.7	ML	CU
		R83-7	36.7 – 37.2	ML	CU
E	▽	R83-1	129.9 – 130.5	SM	UC
		R83-7	74.4 – 75.0	SM	CU
		R83-7	75.0 – 75.5	SM	CU
		R83-7	96.3 – 97.	SM	CU



UNCONFINED COMPRESSION

NOTE



$\sin \phi = \tan \alpha$

$c = \frac{a}{\cos \phi}$

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:
F. Castellanos

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

LABORATORY TEST RESULTS
BEDROCK FOUNDATION AT OUTLET WORKS

SUBMITTED BY:

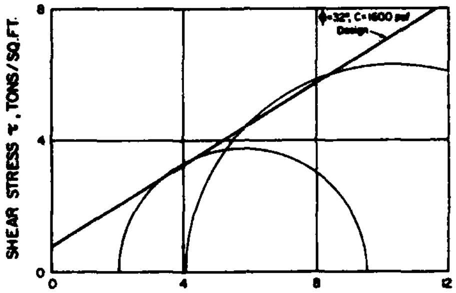
DATE APPROVED:

SPEC. NO. DACW09-____ B-____

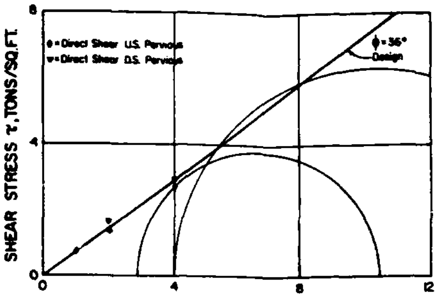
DISTRICT FILE NO.

SHEET

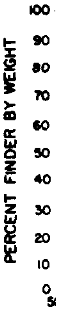
2

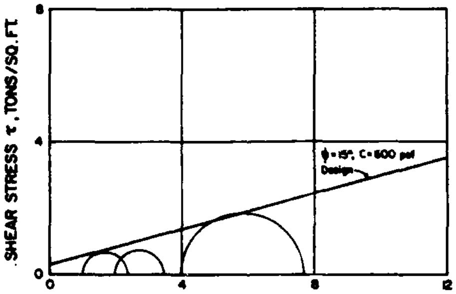


R-TEST PERVIOUS MATERIAL

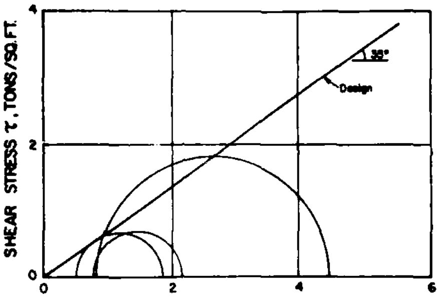


S-TEST PERVIOUS MATERIAL

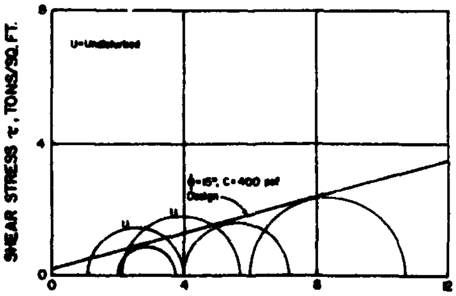




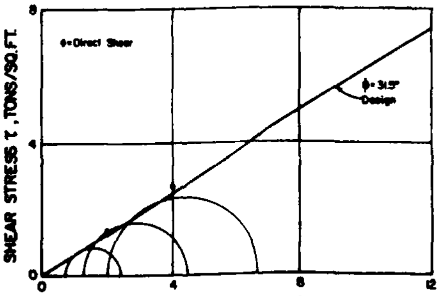
R-TEST, RANDOM MATERIAL



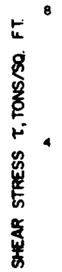
S-TEST, RANDOM MATERIAL



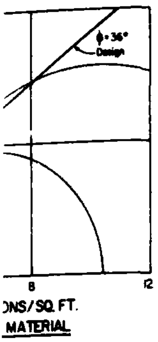
R-TEST, CORE MATERIAL



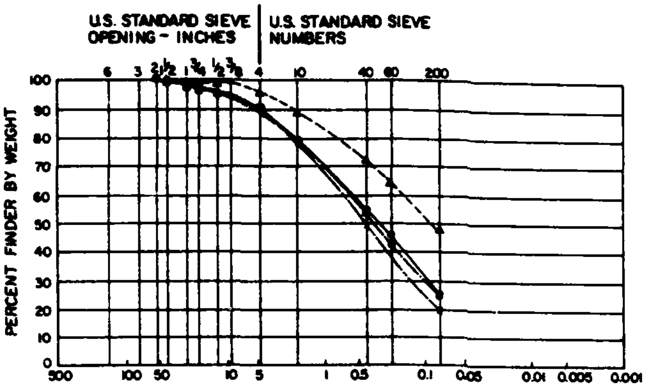
S-TEST CORE MATERIAL



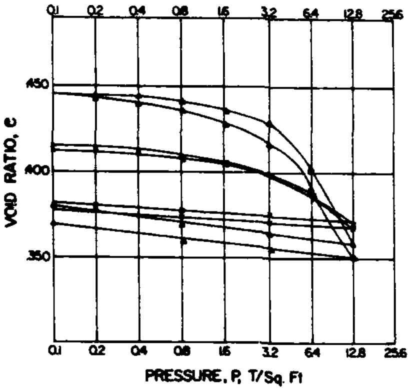
LUE ENGINEERING PAYS



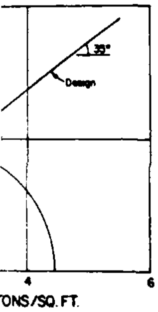
ONS/SQ. FT.
MATERIAL



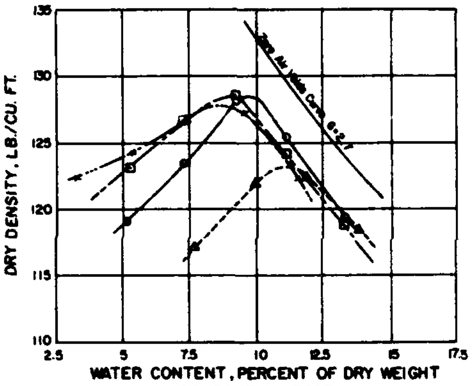
GRADATION CURVES



CONSOLIDATION TESTS



TONS/SQ. FT.
MATERIAL

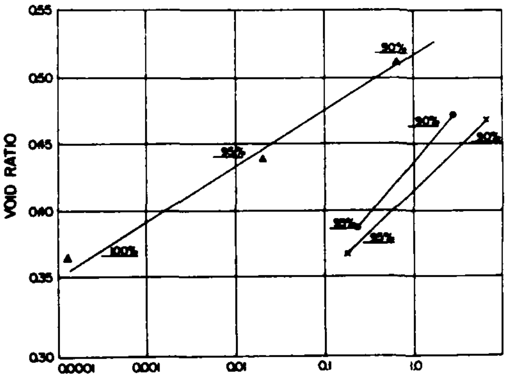


COMPACTION TEST

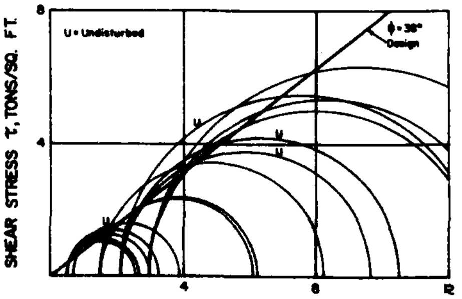
ASTM D 698-70

LEGEND

- Down Stream Pervious Material
- Up Stream Pervious Material
- Up Stream Random Material
- Core Material



COEFFICIENT OF PERMEABILITY @ 20° C

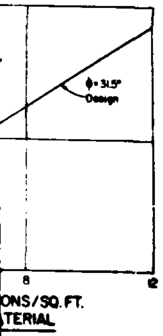


S-TEST FOUNDATION

NOTE:

1. Remolded samples compacted to 95% of maximum density (ASTM 698) at Opt. +2% moisture content except samples for permeability tests were compacted to 90 and 95% at Opt. moisture content.

2. See appendix for detailed test results.



ONS/SQ. FT.
TERIAL

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE I GENERAL DESIGN MEMORANDUM

PRADO DAM

LABORATORY TEST RESULTS
EXISTING EMBANKMENT
AND FOUNDATION

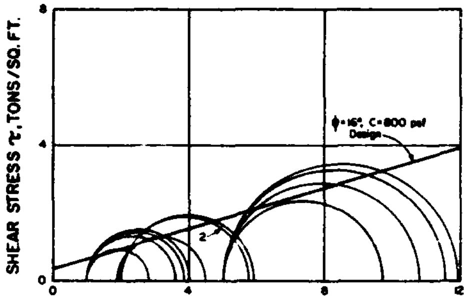
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-____
DISTRICT FILE NO.
SHEET

PLATE B-[illegible]

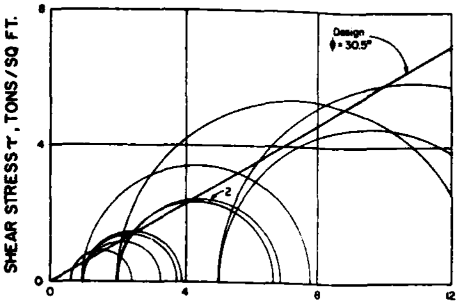
SAFETY PAYS

1

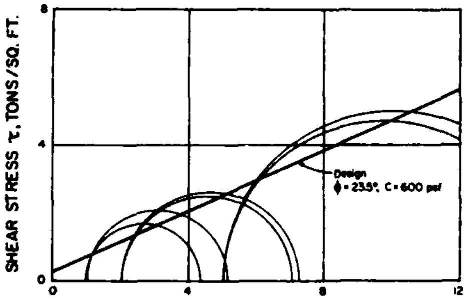
2



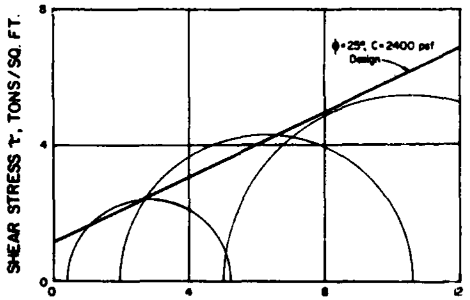
R-TEST, ZONE II MATERIAL



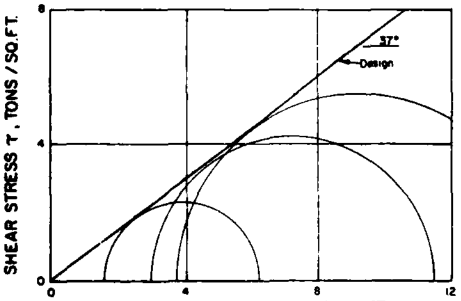
S-TEST, ZONE II MATERIAL



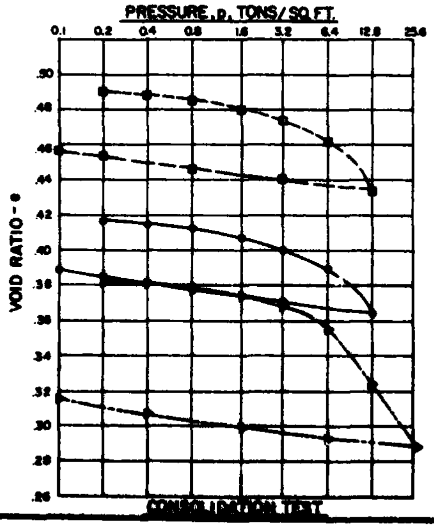
Q-TEST, ZONE II MATERIAL



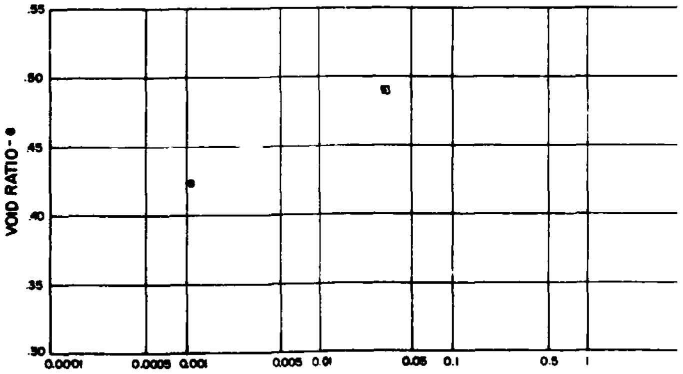
R-TEST, ZONE I MATERIAL



S-TEST, ZONE I MATERIAL

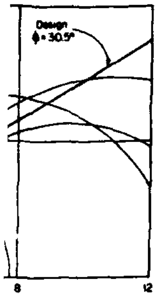


CONSOLIDATION TEST

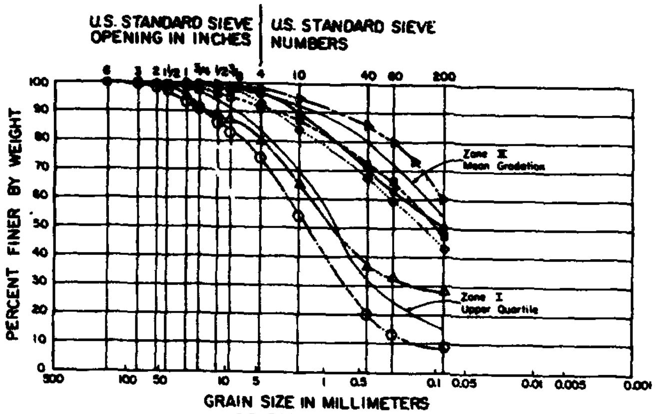


PERMEABILITY TESTS

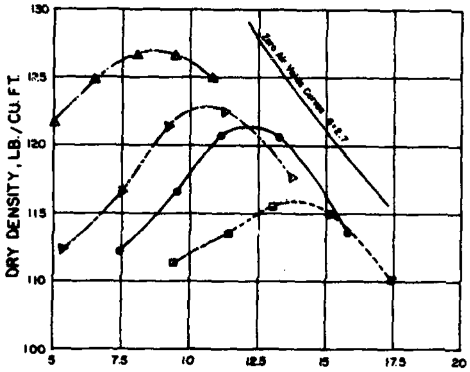
LUE ENGINEERING PAYS



)NS/SQ.FT.
ITERIAL



GRADATION CURVES



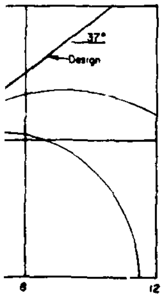
COMPACTION TEST
ASTM D 698-70

LEGEND

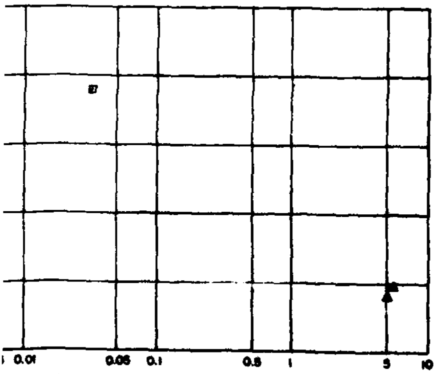
⊙—·—·—⊙ ZONE I MATERIAL
▲—·—·—▲ ZONE I MATERIAL
▷—·—·—▶ ZONE II MATERIAL
○———○ ZONE II MATERIAL
⊡- - - - -⊡ ZONE II MATERIAL
◇·········◇ ZONE II MATERIAL

NOTES:

1. SAMPLES WEHE COMPACTED TO 98% OF MAXIMUM DENSITY AT OPT. AND OPT + 2% MOISTURE
2. SEE APPENDIX FOR DETAILED LABORATORY TEST RESULTS.



'ONS/SQ.FT.
ATERIAL



NT OF PERMEABILITY (k) FT./DAY
PERMEABILITY TESTS

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

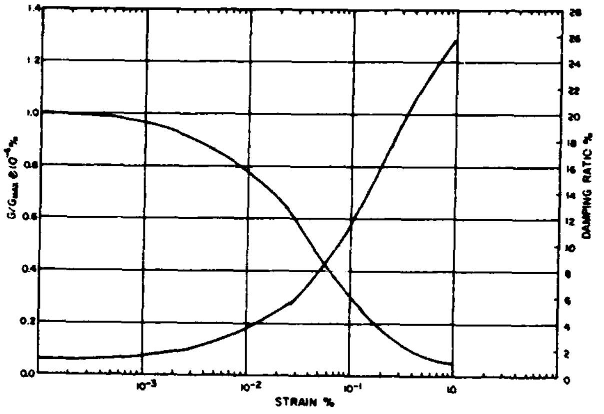
PRADO DAM

LABORATORY TEST RESULTS
ZONE I & II

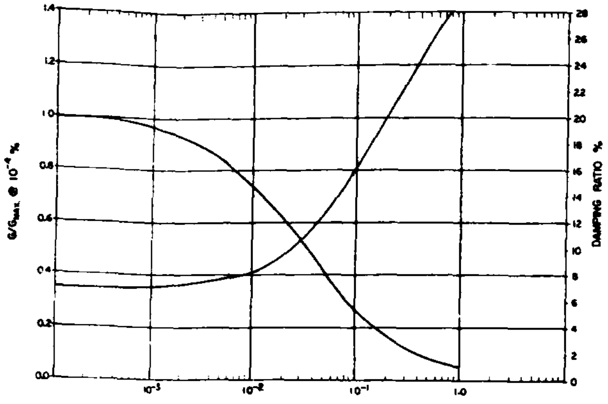
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___-B-___
DISTRICT FILE NO.
SHEET

SAFETY PAYS

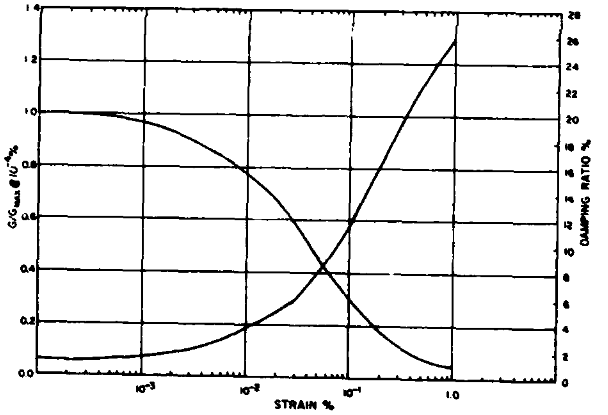
2



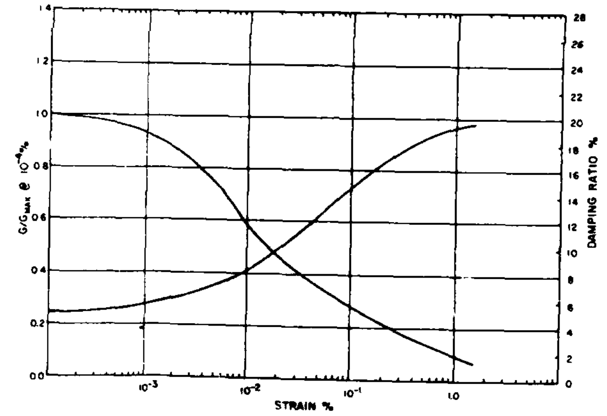
PERVIOUS MATERIAL



RANDOM MATERIAL

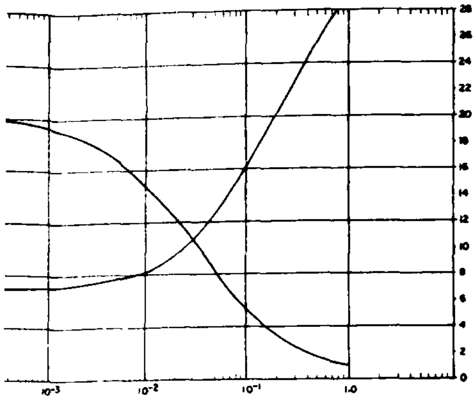


FOUNDATION MATERIAL

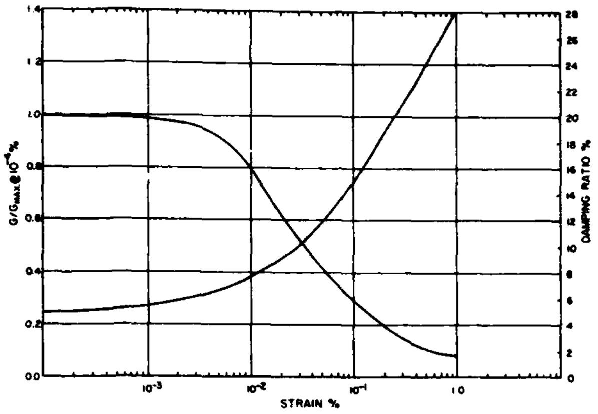


ZONE I BORROW

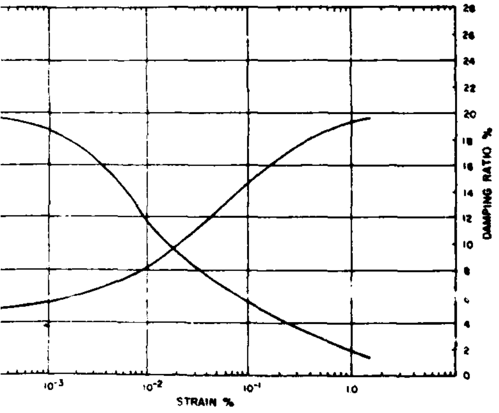
ALUE ENGINEERING PAYS



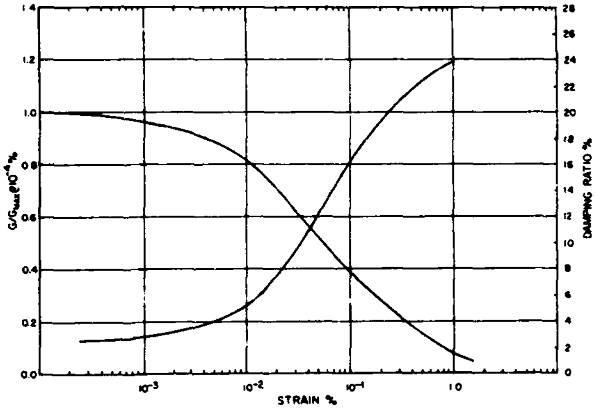
RANDOM MATERIAL



CORE MATERIAL



ZONE I BORROW



ZONE II BORROW

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

DAM FOUNDATION, EMBANKMENT AND BORROW
DYNAMIC PROPERTIES

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

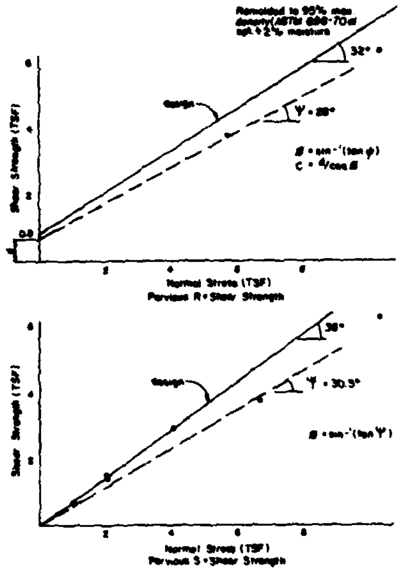
DISTRICT FILE NO.

SHEET

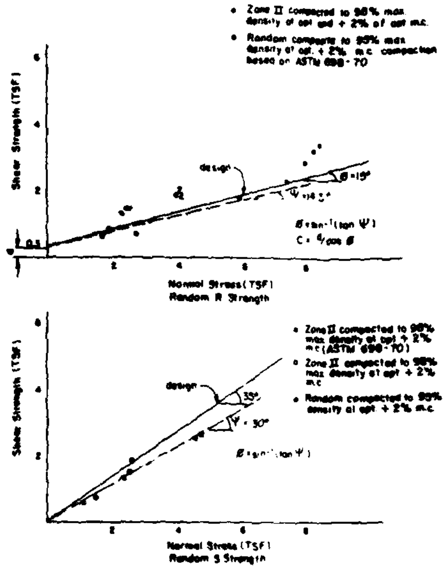
PLATE B-65

SAFETY PAYS

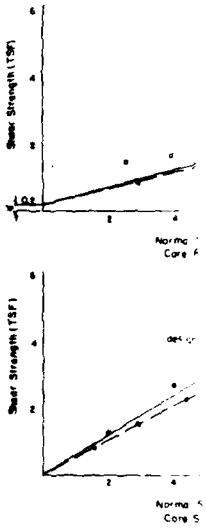
2



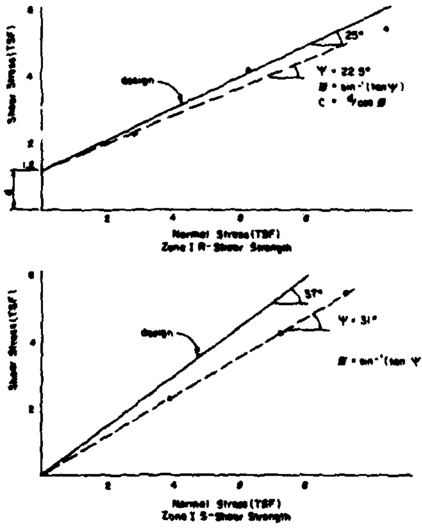
PERVIOUS DESIGN SHEAR STRENGTH
AND P-q PLOTS



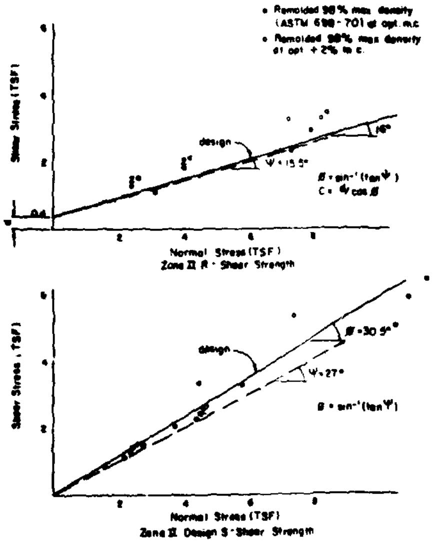
RANDOM DESIGN SHEAR STRENGTH
AND P-q PLOT



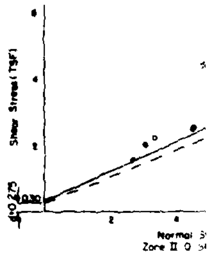
CORE DESIGN S
AND P-



ZONE I MATERIAL DESIGN SHEAR STRENGTH
AND P-q PLOTS

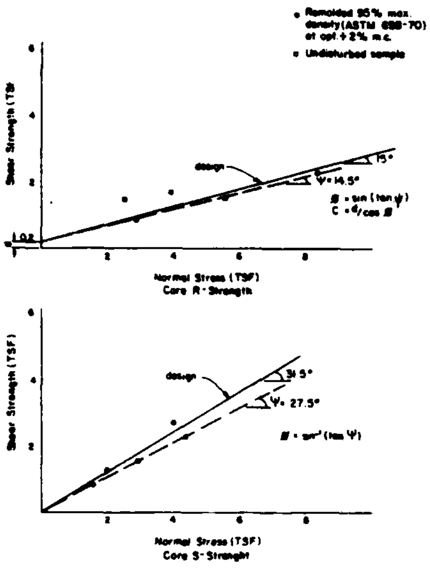


ZONE II DESIGN SHEAR STRENGTH
AND P-q PLOT

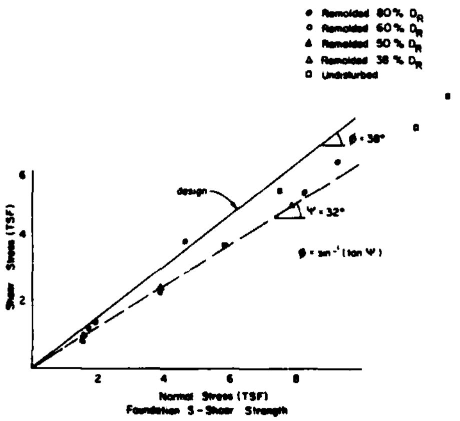


ZONE II DESIGN
AND P

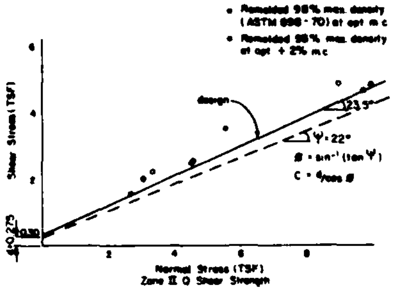
UE ENGINEERING PAYS



CORE DESIGN SHEAR STRENGTH AND P-q PLOTS

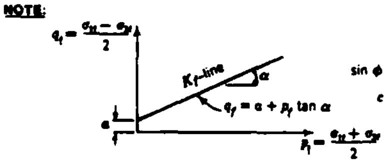


FOUNDATION DESIGN SHEAR STRENGTH AND P-q PLOTS



ZONE II DESIGN SHEAR STRENGTH AND P-q PLOT

NOTE:



$\sin \phi = \tan \alpha$

$c = \frac{a}{\cos \phi}$

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

DAM FOUNDATION, EMBANKMENT AND BORROW
DESIGN SHEAR STRENGTHS

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

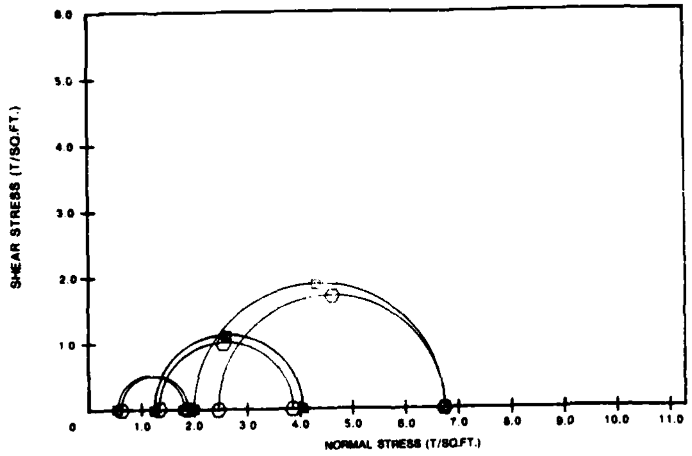
DISTRICT FILE NO.

SHEET

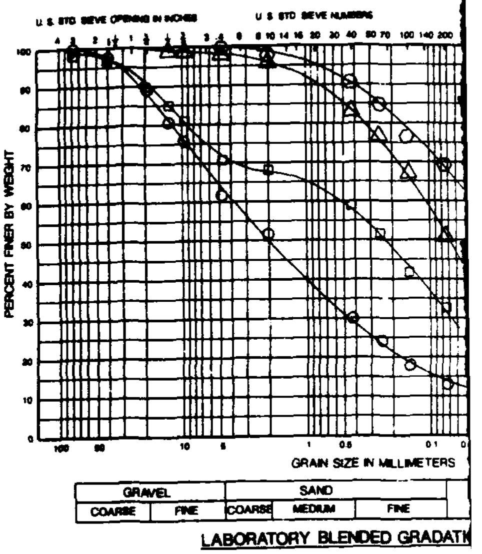
PLATE B-86

SAFETY PAYS

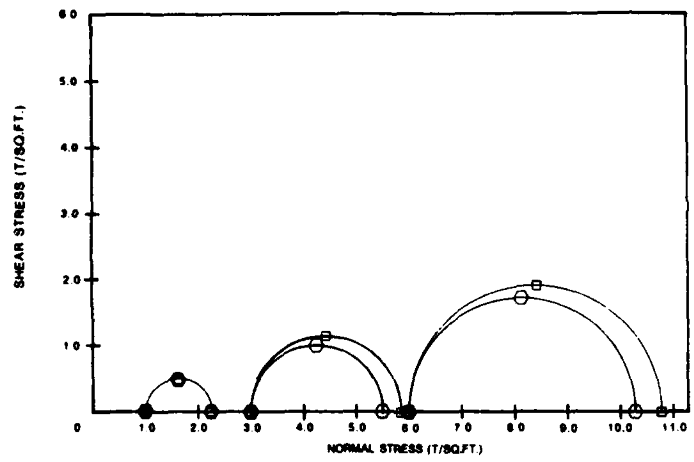
2



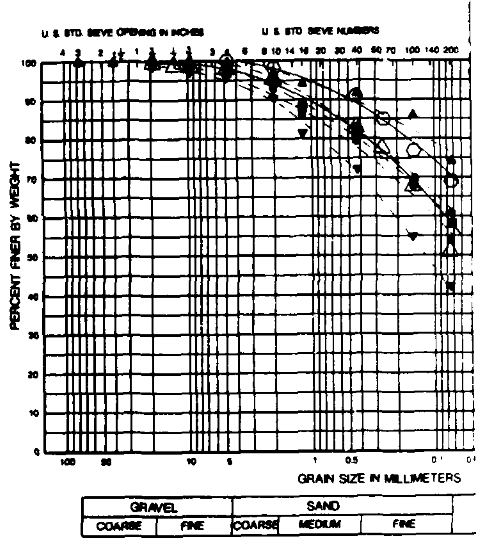
CONSOLIDATED-DRAINED TRIAXIAL SHEAR TEST



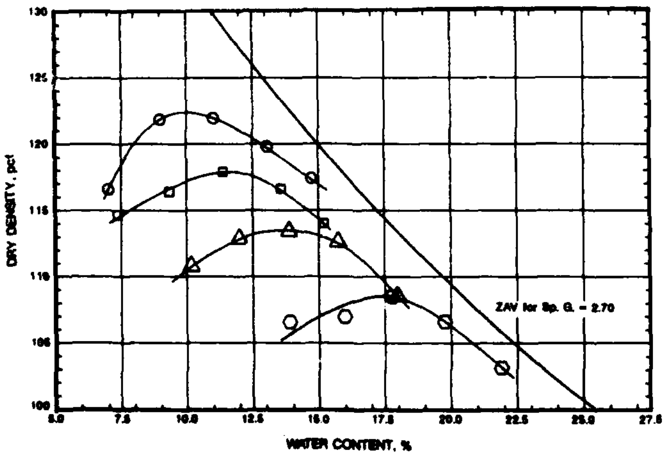
LABORATORY BLENDED GRADATI



CONSOLIDATED-UNDRAINED TRIAXIAL SHEAR TEST

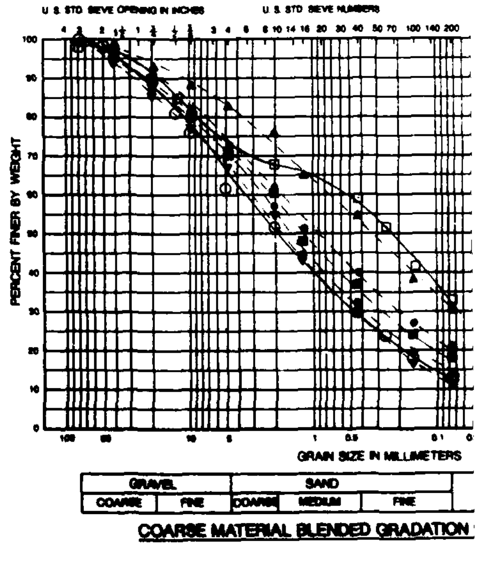


FINE MATERIAL BLENDED GRADATION C

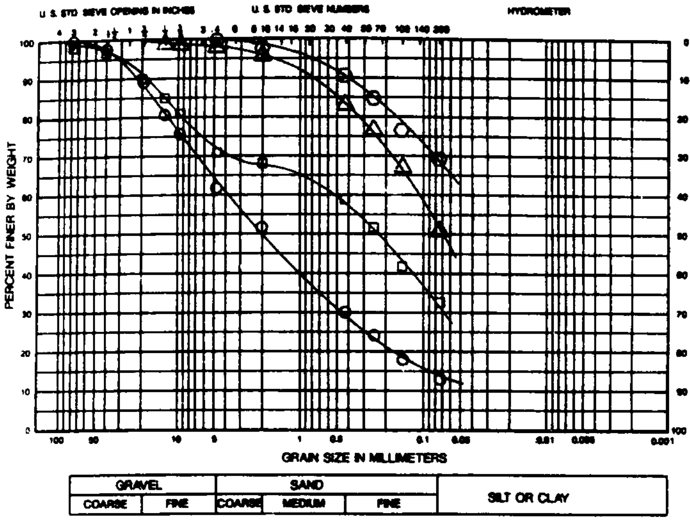


COMPACTION TESTS

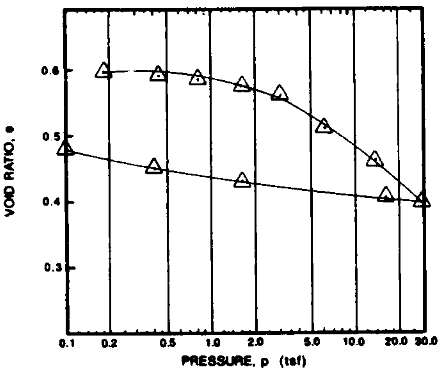
ASTM D 698-78, METHOD B



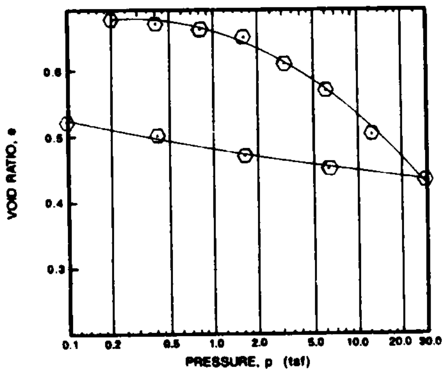
COARSE MATERIAL BLENDED GRADATION



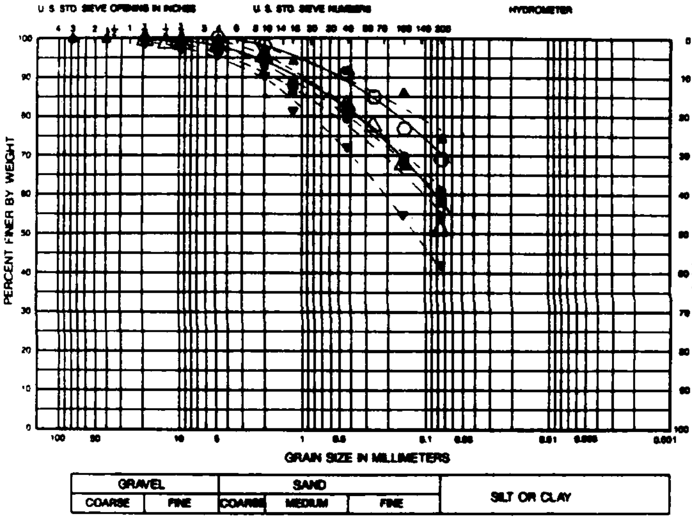
LABORATORY BLENDED GRADATION CURVES



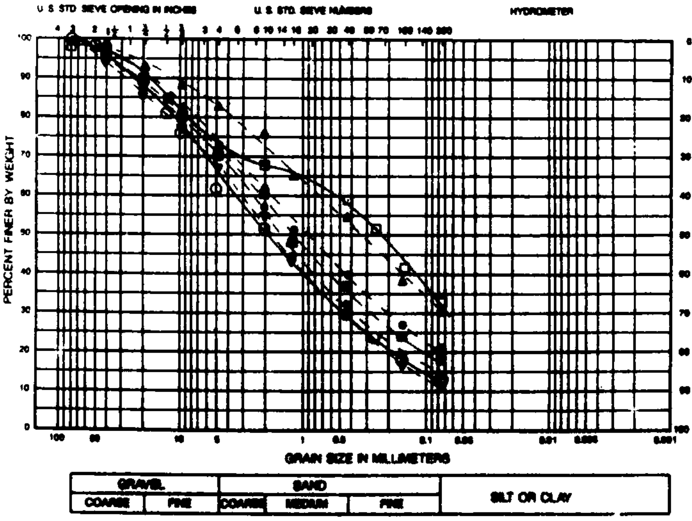
CONSOLIDATION TESTS



CONSOLIDATION TESTS



FINE MATERIAL BLENDED GRADATION CURVES (0-40 FT.)



COARSE MATERIAL BLENDED GRADATION CURVES (0-40 FT.)

LEGEND

△ FINE BLEND 1	▲ UPPER LIMITS
⬡ FINE BLEND 2	● UPPER QUARTILE
□ COARSE BLEND 1	■ MEAN (AVERAGE)
○ COARSE BLEND 2	● LOWER QUARTILE
	▼ LOWER LIMITS

NOTES:

1. SEE PLATE 38 FOR LEGEND AND CLASSIFICATION SYSTEM
2. TEST HOLES WERE DRILLED USING A 24" BUCKET AUGER IN APRIL 1967.
3. THE DEPTH TO GROUNDWATER IS APPROXIMATE AND IS EXPECTED TO VARY SEASONALLY AND FROM YEAR TO YEAR.
4. THE LOG OF THAT HOLE INDICATES THE GEOTECHNICAL CONDITIONS AT THAT LOCATION AT THAT PARTICULAR TIME. SOIL CONDITIONS CAN CHANGE WITH TIME. THE STRATIFICATION LINES SHOWN ON THE LOGS REPRESENT THE APPROXIMATE BOUNDRY BETWEEN SOIL TYPES AND THE TRANSITION MAY BE GRADUAL OR ABRUPT.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

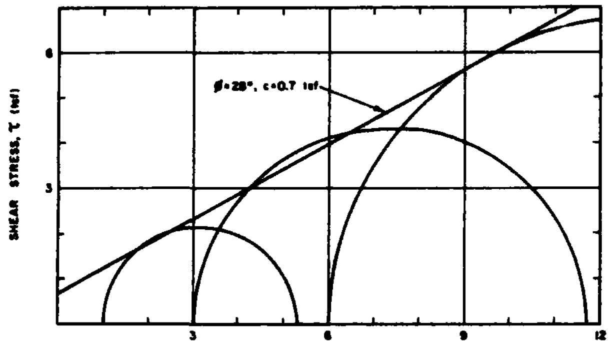
PRADO DAM

LABORATORY TEST RESULTS
BORROW AREA 2 1967

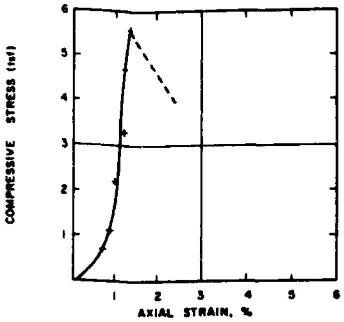
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

1

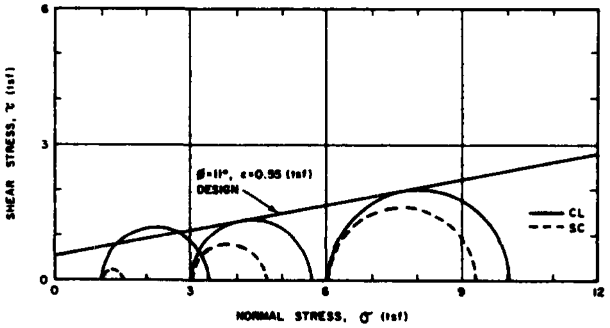
2



Q-TEST, UNDISTURBED CL

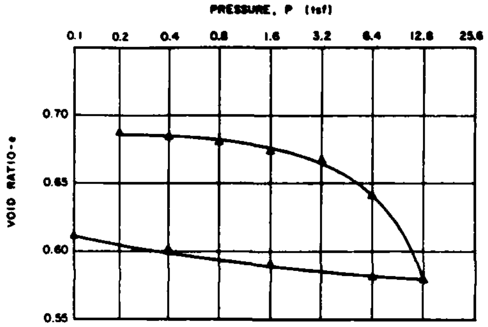


UNCONFINED COMPRESSION TEST, UNDISTURBED CL-ML

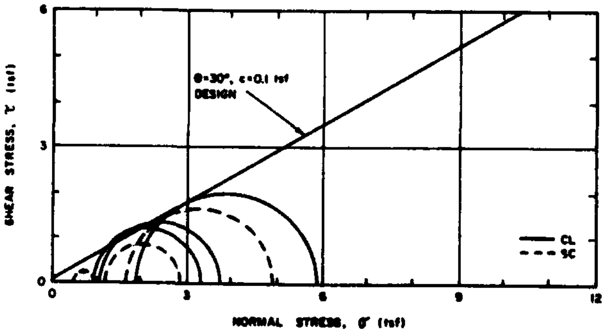


R-TEST, UNDISTURBED CL, REMOLDED SC

(SEE NOTE 1)

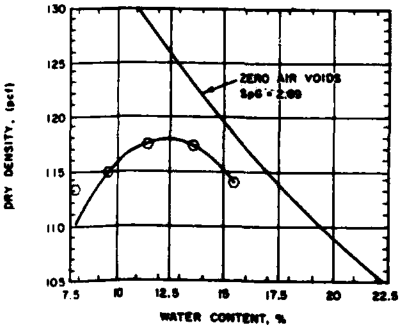


CONSOLIDATION TEST, UNDISTURBED CL



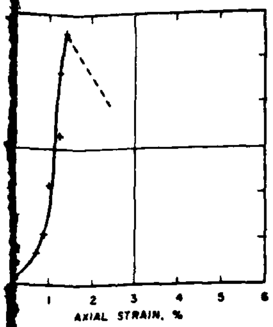
S-STRENGTH, UNDISTURBED CL, REMOLDED SC

(FROM R TEST, SEE NOTE 1)

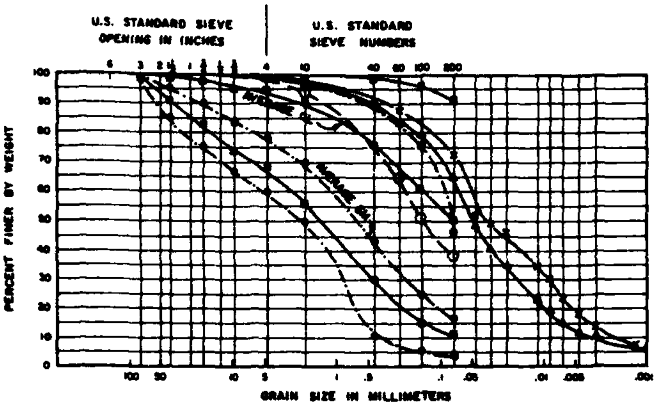


COMPACTION TEST, SC

ASTM D 698-78, METHOD D



ONFINED COMPRESSION TEST, UNDISTURBED CL - ML

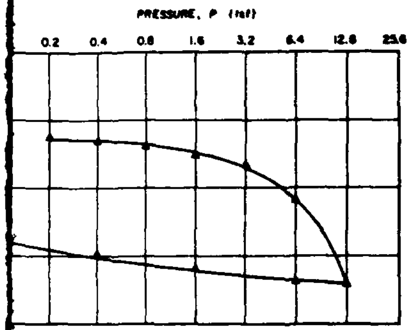


GRADATION CURVES

-●- UPPER LIMIT, -●- AVERAGE, -●- LOWER LIMIT, SC-CL FOUNDATION
-●- UPPER LIMIT, -●- AVERAGE, -●- LOWER LIMIT, SM FOUNDATION
△, ×, ○, SEE LEGEND

LEGEND

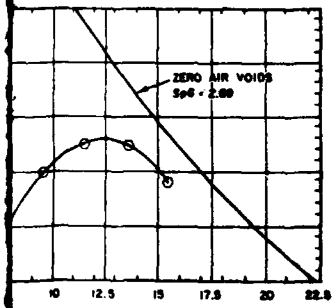
△———△	UNDISTURBED CL SAMPLE
○———○	REMOLDED SC SAMPLE (SEE NOTE 1)
×———×	UNDISTURBED CL-ML SAMPLE



CONSOLIDATION TEST, UNDISTURBED CL

NOTES:

1. SC IS REMOLDED TO 87% OF MAXIMUM DRY DENSITY AT -1% OPTIMUM MOISTURE CONTENT.
2. SEE APPENDIX FOR DETAILED LABORATORY TEST RESULTS.



COMPACTION TEST, SC

ASTM D 698-78, METHOD B

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY: J.R.B.

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
LABORATORY TEST RESULTS
AUXILIARY DIKE
FOUNDATION

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

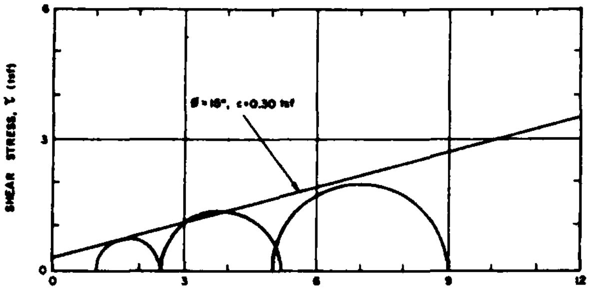
DISTRICT FILE NO.

SHEET

PLATE B-66

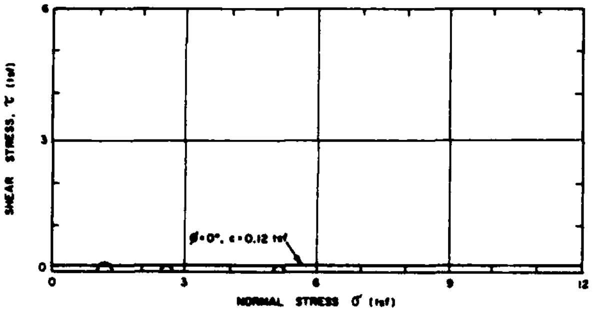
1

2



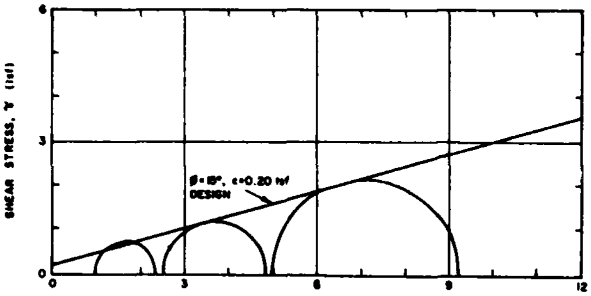
Q-TEST, UNDISTURBED CL (ABOVE WATER TABLE)

(◇ UNDISTURBED CL)



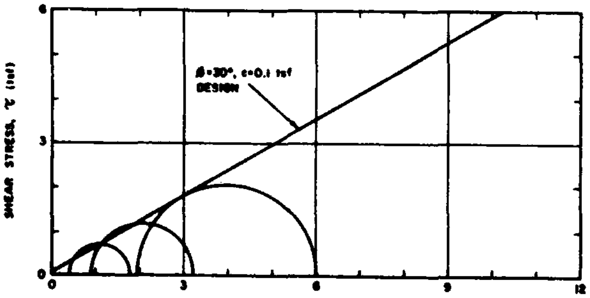
Q-TEST, UNDISTURBED CL (BELOW WATER TABLE)

(▽ UNDISTURBED CL)



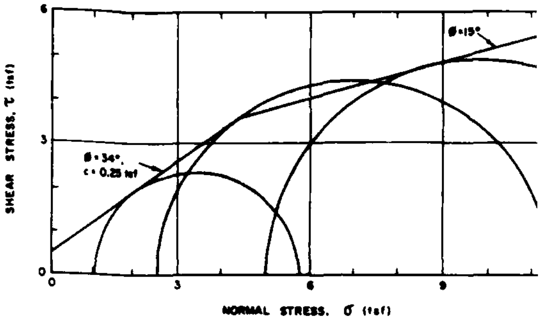
R-TEST, UNDISTURBED CL

(△ UNDISTURBED CL)



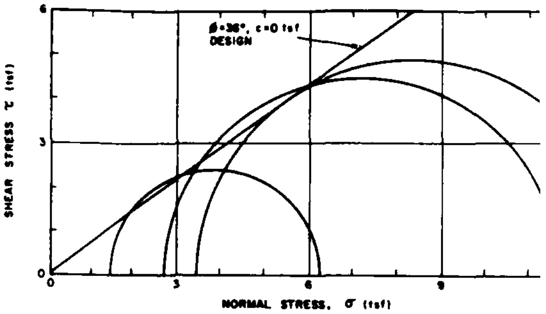
S-TEST, UNDISTURBED CL

(△ UNDISTURBED CL)



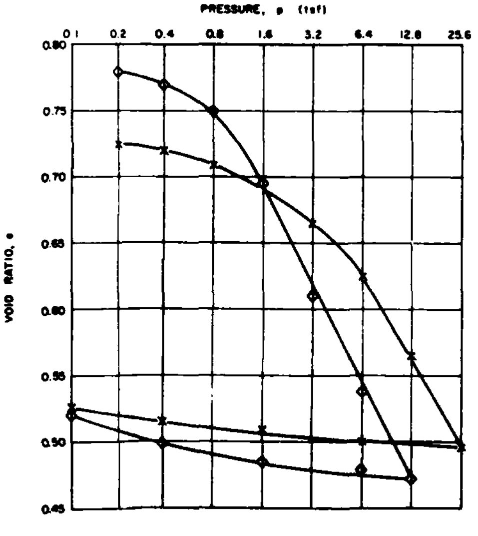
R-TEST, REMOLDED SP

(SEE NOTE 1)

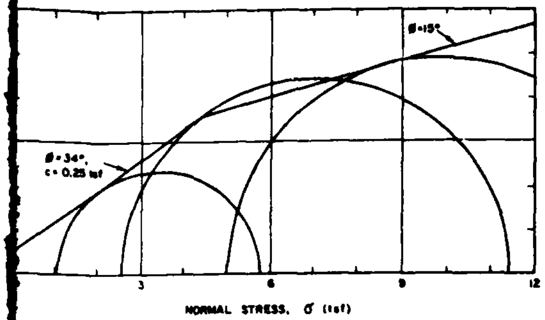


S-TEST, REMOLDED SP

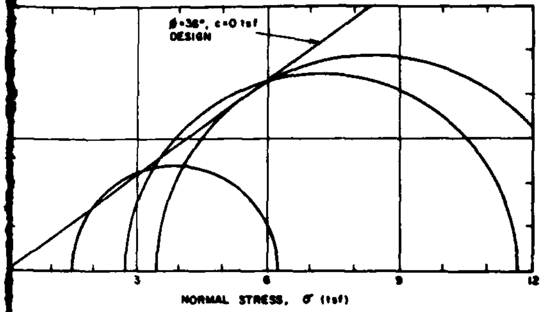
(SEE NOTE 1)



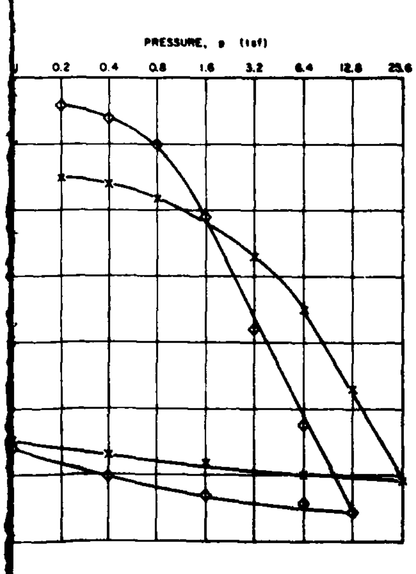
CONSOLIDATION TEST, UNDISTURBED CL AND SC-SM



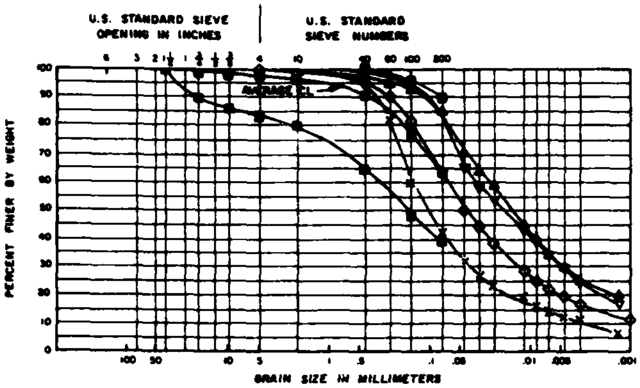
R-TEST, REMOLDED SP
(SEE NOTE 1)



S-TEST, REMOLDED SP
(SEE NOTE 1)

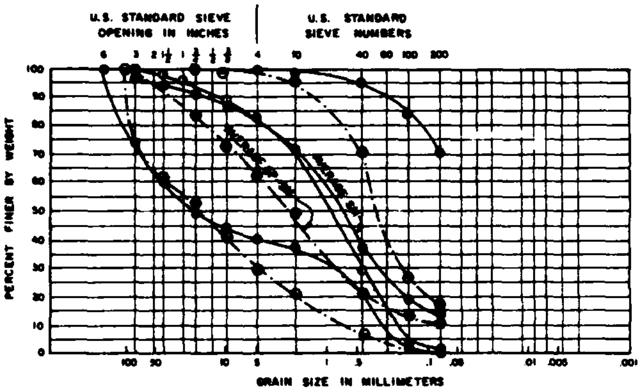


OLIDATION TEST, UNDISTURBED CL AND SC-SM



GRADATION CURVES, CL

-●- UPPER LIMIT, -■- AVERAGE, -●- LOWER LIMIT, CL FOUNDATION
◇, ×, △, ▽, SEE LEGEND



GRADATION CURVES, SM AND SP-SM

-●- UPPER LIMIT, -●- AVERAGE, -●- LOWER LIMIT, SM FOUNDATION
-●- UPPER LIMIT, -●- AVERAGE, -●- LOWER LIMIT, SP-SM FOUNDATION
○ SEE LEGEND

LEGEND

- ◇ UNDISTURBED CL (ABOVE WATER TABLE)
- × UNDISTURBED SC-SM
- ▲ UNDISTURBED CL
- ▼ UNDISTURBED CL (BELOW WATER TABLE)
- ○ REMOLDED SP (SEE NOTE 1)

NOTES:

1. SP IS REMOLDED TO 85% OF MAXIMUM DRY DENSITY ($\gamma_{dry\ max.}$ = 121 pcf) AND SATURATED FOR R TEST.
2. SEE APPENDIX FOR DETAILED LABORATORY TEST RESULTS.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
LABORATORY TEST RESULTS
DIKE AT ALCOA ALUMINUM PLANT
FOUNDATION

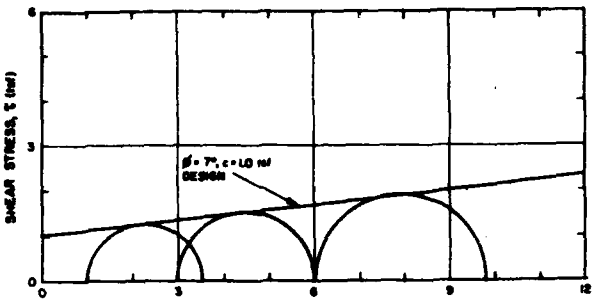
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET

PLATE B-90

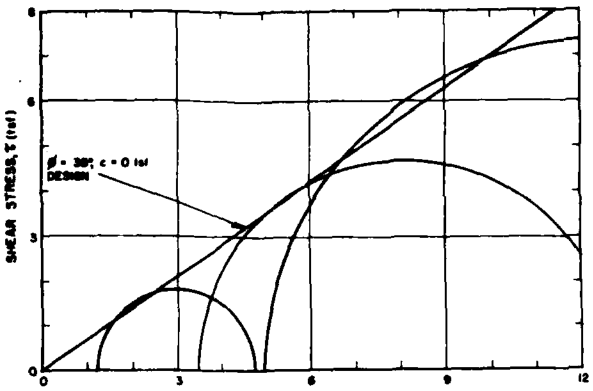
SAFETY PAYS

1

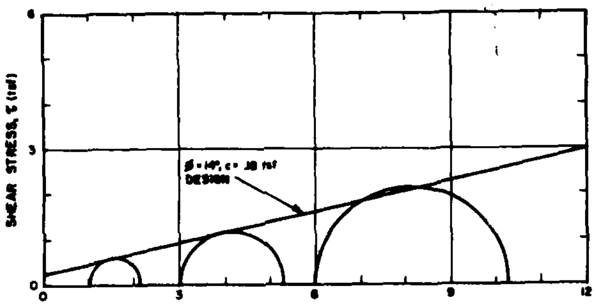
2



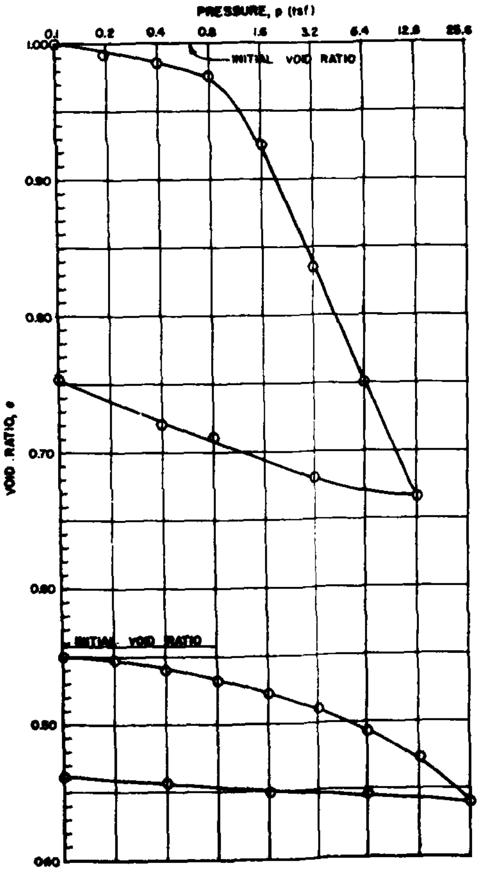
Q-TEST, UNDISTURBED CH



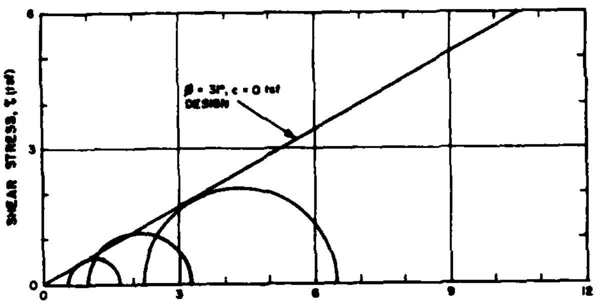
S-STRENGTH, UNDISTURBED CL-ML
(FROM R TEST)



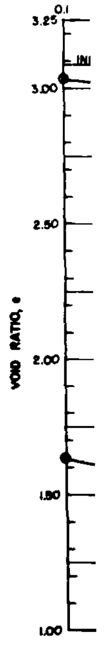
R-TEST, UNDISTURBED CH

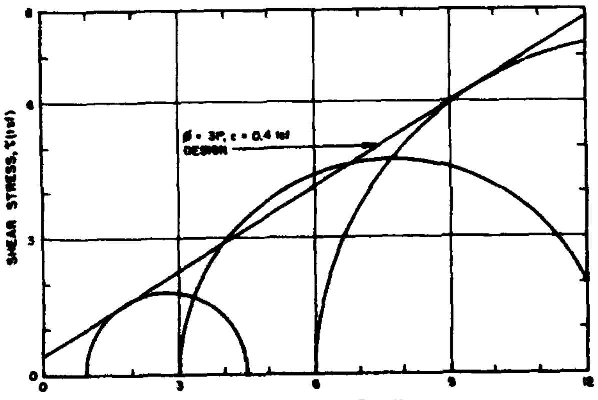


CONSOLIDATION TEST, UNDISTURBED CH AND CL-ML

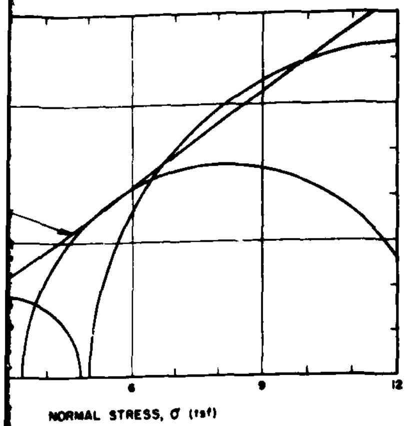


S-STRENGTH, UNDISTURBED CH
(FROM R TEST)

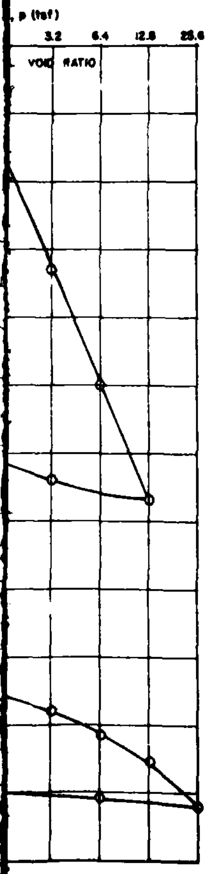




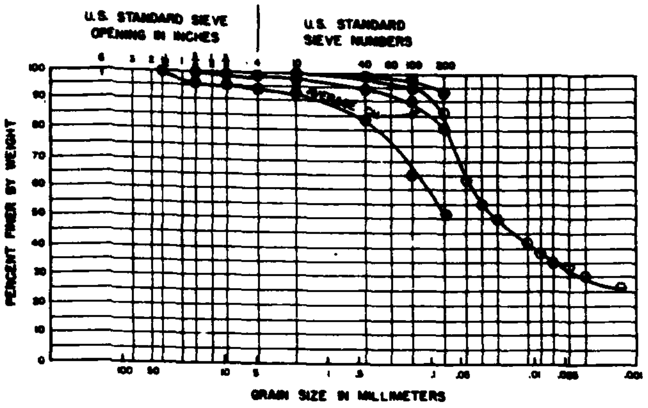
R-TEST, UNDISTURBED CL-ML



STRENGTH, UNDISTURBED CL-ML
(FROM R TEST)

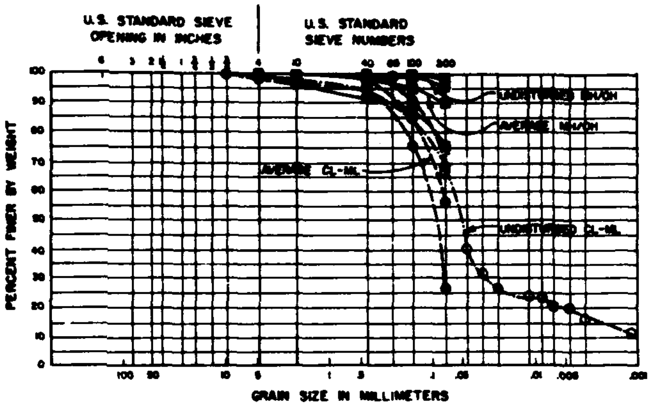


TURBED CH AND CL-ML



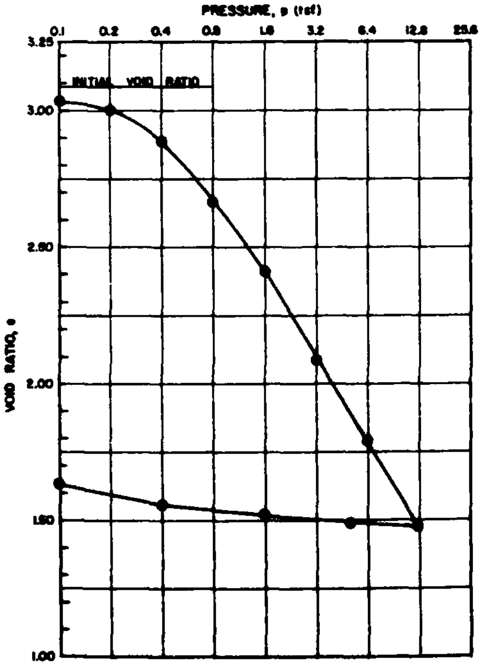
GRADATION CURVES, CH FOUNDATION

—●— UPPER LIMIT, —●— AVERAGE, —●— LOWER LIMIT, CH FOUNDATION
—○— SEE LEGEND



GRADATION CURVES, MH/OH AND CL-ML

—■— UPPER LIMIT, —■— AVERAGE, —■— LOWER LIMIT, MH/OH FOUNDATION
-●- UPPER LIMIT, -●- AVERAGE, -●- LOWER LIMIT, CL-ML FOUNDATION
—●—, -○- SEE LEGEND



CONSOLIDATION TEST, UNDISTURBED MH/OH

LEGEND

○——○ UNDISTURBED CH
○——○ UNDISTURBED CL-ML
●——● UNDISTURBED MH/OH

NOTES:

1. SEE APPENDIX FOR DETAILED LABORATORY TEST RESULTS.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:
PParquette

CHECKED BY:

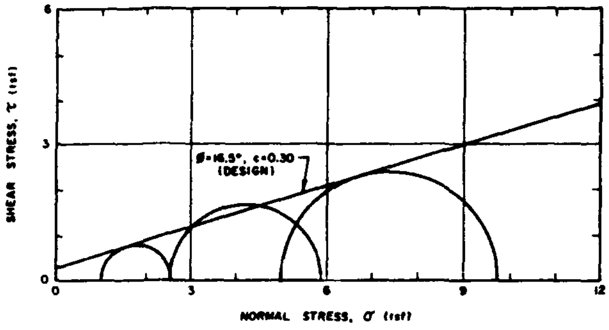
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
LABORATORY TEST RESULTS
DIKE AT CALIFORNIA INSTITUTION FOR WOMEN
FOUNDATION

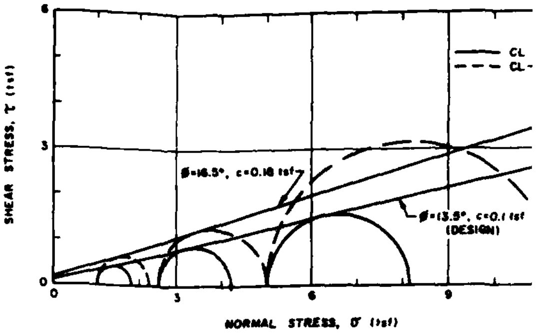
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-90

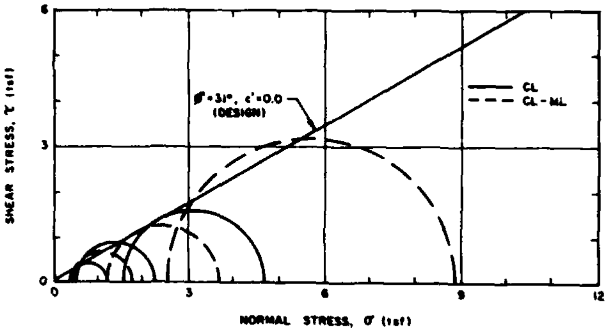
2



Q-TEST, UNDISTURBED CL

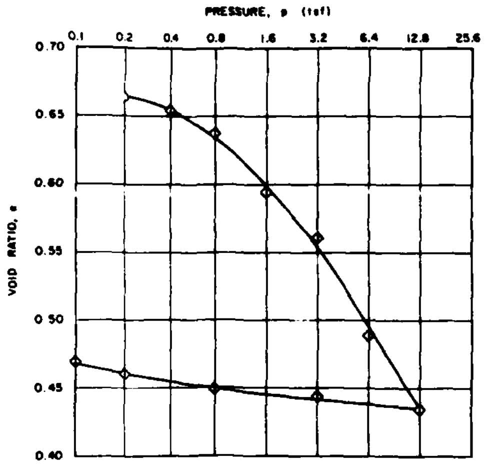


R-TEST, UNDISTURBED CL AND CL-ML

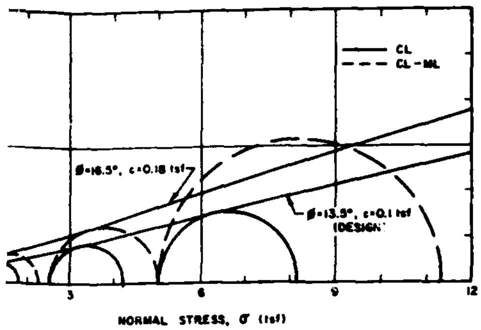


S-STRENGTH, UNDISTURBED CL

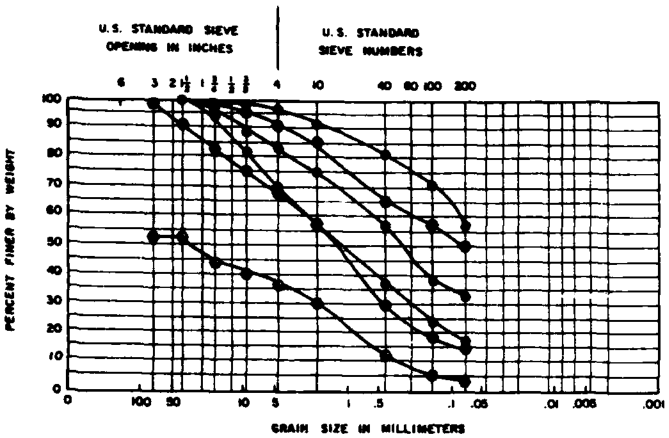
(FROM R TEST)



CONSOLIDATION TEST, UNDISTURBED CL

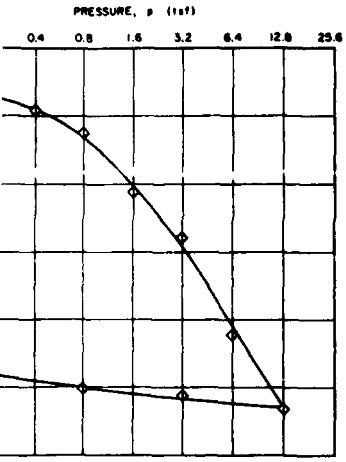


R-TEST, UNDISTURBED CL AND CL-ML

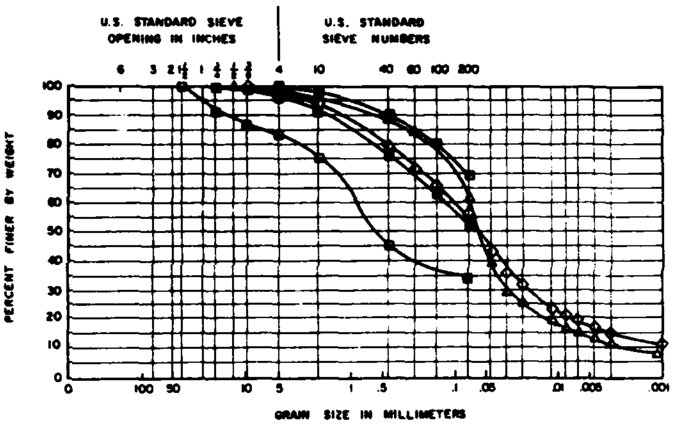


GRADATION CURVES

●—● UPPER LIMIT, ●—● AVERAGE, ●—● LOWER LIMIT, UPPER SM FOUNDATION
●—● UPPER LIMIT, ●—● AVERAGE, ●—● LOWER LIMIT, LOWER SM FOUNDATION



LIDATION TEST, UNDISTURBED CL



GRADATION CURVES

■—■ UPPER LIMIT, ■—■ AVERAGE, ■—■ LOWER LIMIT, CL FOUNDATION
◇, △ SEE LEGEND

LEGEND

◇—◇ UNDISTURBED CL
△—△ UNDISTURBED CL - ML

NOTES:
1. SEE APPENDIX FOR DETAILED LABORATORY TEST RESULTS.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:
J.T.B.

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

LABORATORY TEST RESULTS
DIKE AT CORONA SEWAGE TREATMENT PLANT
FOUNDATION

SUBMITTED BY:

DATE APPROVED:

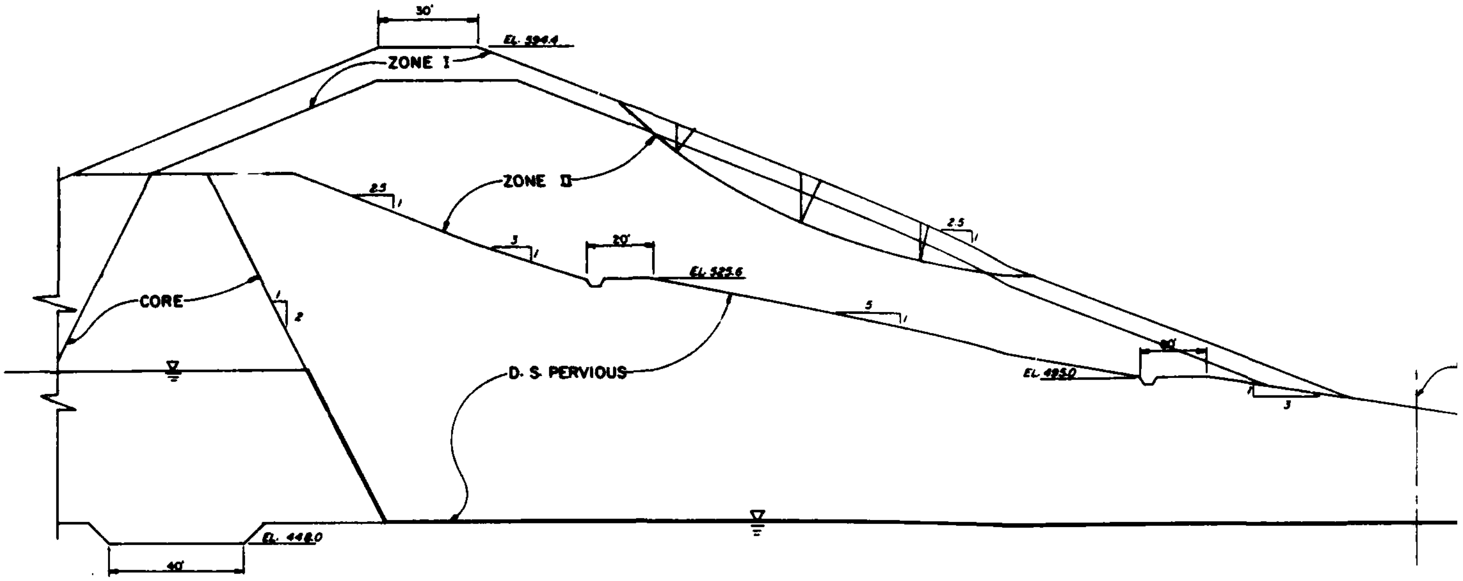
SPEC. NO. DACW 09-____-B-____

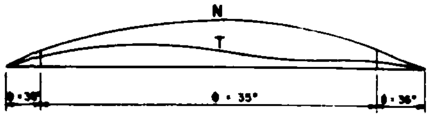
DISTRICT FILE NO.

SHEET

PLATE B-91

2





STEADY SEEPAGE-POOL @ EL. 500

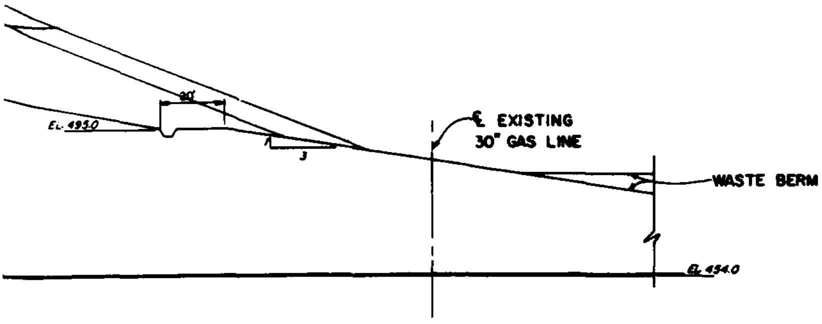
SCALE 1 IN = 2500 lbs.

TABLE OF DESIGN VALUES

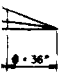
MATERIAL	SHEAR STRENGTHS						UNIT WEIGHTS	
	Q		R		S		γ_m (PCF)	γ_{Sat} (PCF)
	C(PSF)	φ	C(PSF)	φ	C(PSF)	φ		
ZONE I	—	37°	2400	25°	—	37°	135.3	—
ZONE II	600	23.5°	800	16°	—	30.5°	128.5	—
U. S. PERVIOUS	600	23.5°	1600	32°	—	36°	135.3	139.5
RANDOM	600	23.5°	600	15°	—	35°	134.9	139.4
CORE	600	23.5°	400	15°	—	31.5°	132.2	136.0
D. S. PERVIOUS	600	23.5°	1600	32°	—	36°	135.3	139.5
FOUND. EL. 419-454	—	—	1000	16°	—	38°	115.0	130.6
FOUND. EL. 380-419	—	—	—	—	—	38°	115.0	130.6
U. S. DEBRIS	—	—	200	—	—	28°	—	106.0
D. S. WASTE BERM	—	—	—	—	—	35°	135.3	—

SUMMARY OF FACTORS OF SAFETY

CASE	CONDITION		CALC. F.S.	MIN. ALLOW
I	END OF CONSTRUCTION	U.S. SLOPE	1.4	1.4
		D.S. SLOPE	1.5	1.4
II	SUDDEN DRAWDOWN MAX. POOL		1.0	1.0
III	SUDDEN DRAWDOWN SPILLWAY CREST		1.2	1.2
IV	PARTIAL POOL		1.5	1.5
V	STEADY SEEPAGE		1.5	1.5



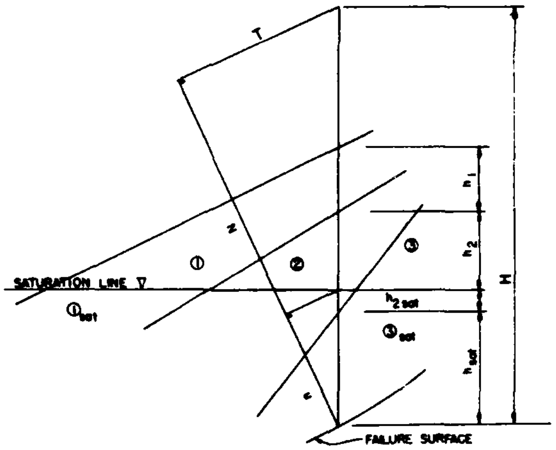
$$FS = \frac{\Sigma N \tan \phi + CL}{\Sigma T}$$
$$= \frac{93850+0}{61402}$$
$$= 1.5$$ MINIMUM COMPUTER F.S. 1.5



L @ EL. 500
500 lbs

SUMMARY OF FACTORS OF SAFETY

CASE	CONDITION		CALC. F.S.	MIN. ALLOW F.S.
I	END OF CONSTRUCTION	U.S. SLOPE	1.4	1.4
		D.S. SLOPE	1.5	1.4
II	SUDDEN DRAWDOWN MAX. POOL		1.0	1.0
III	SUDDEN DRAWDOWN SPILLWAY CREST		1.2	1.2
IV	PARTIAL POOL		1.5	1.5
V	STEADY SEEPAGE		1.5	1.5



$$H = \frac{\gamma_{3\,sat} \times h_{3\,sat} + \gamma_{2\,sat} + \gamma_2 h_2 + \gamma_1 h_1}{\gamma_{water}}$$

$h_1, h_2, h_{2sat}, h_{3sat}$ = LAYER THICKNESS
T = TANGENTIAL DRIVING FORCE
N = NORMAL FORCE
u = PORE PRESSURE

TYPICAL FORCE DIAGRAM
NOT TO SCALE

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

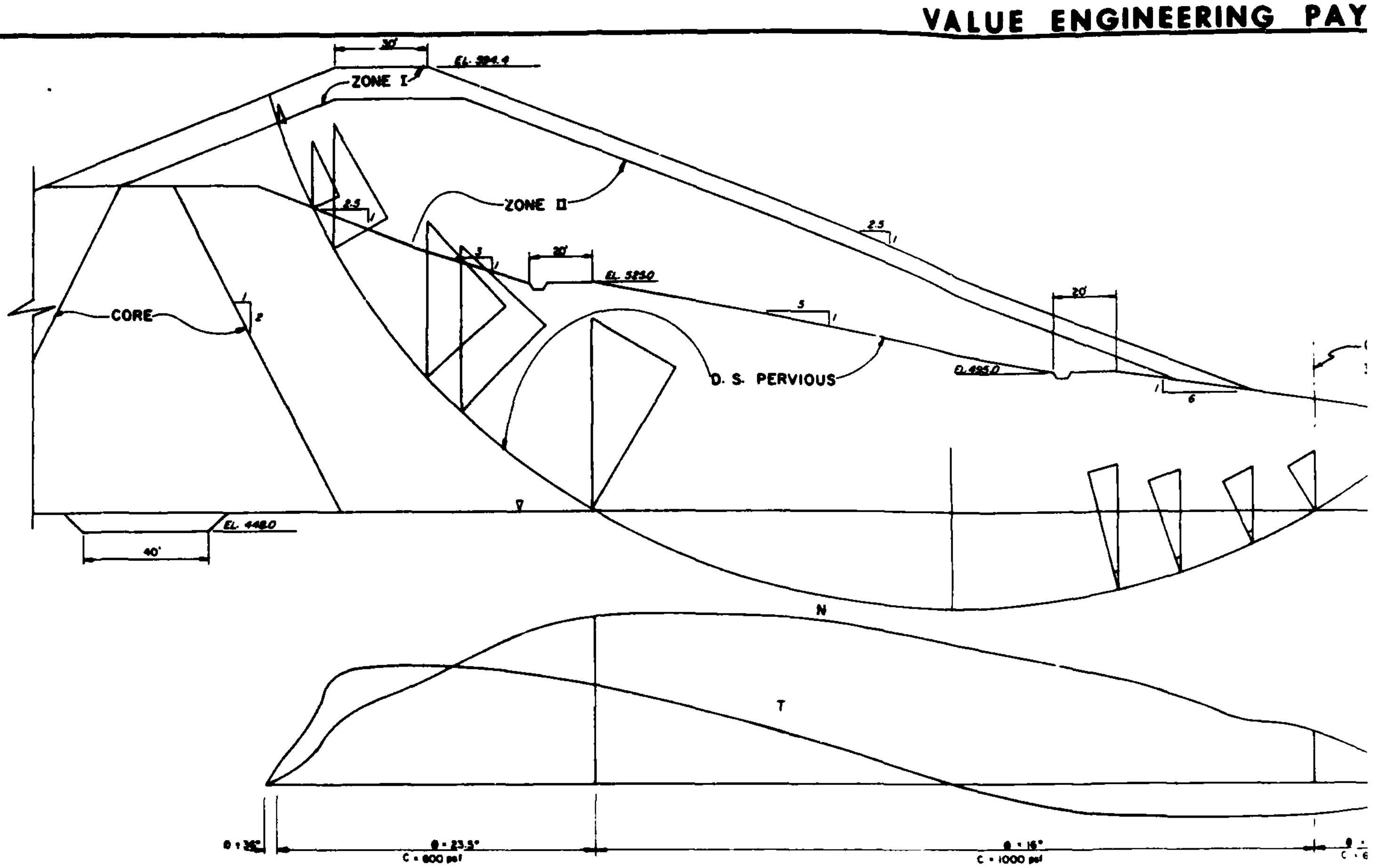
SLOPE STABILITY
STEADY SEEPAGE

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09- ____ B- ____
DISTRICT FILE NO.
SHEET

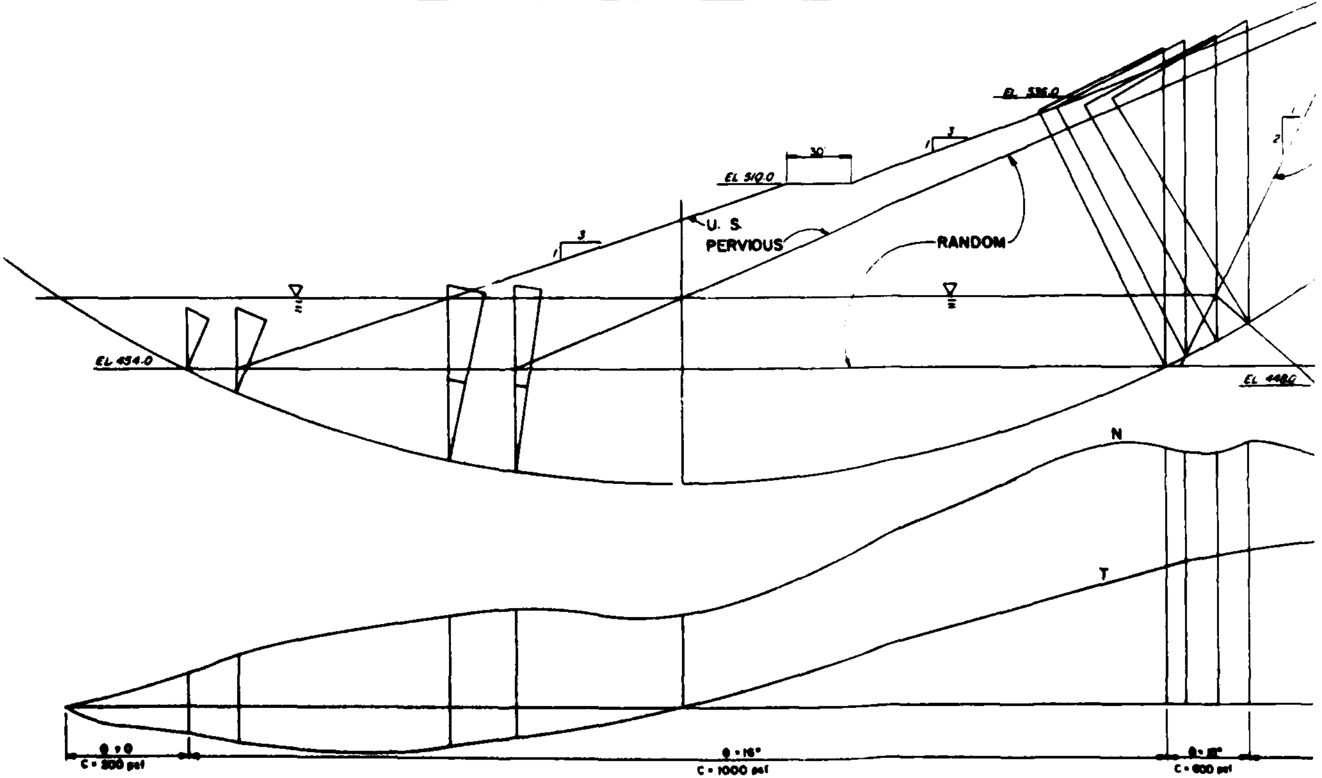
PLATE B-02

1

2

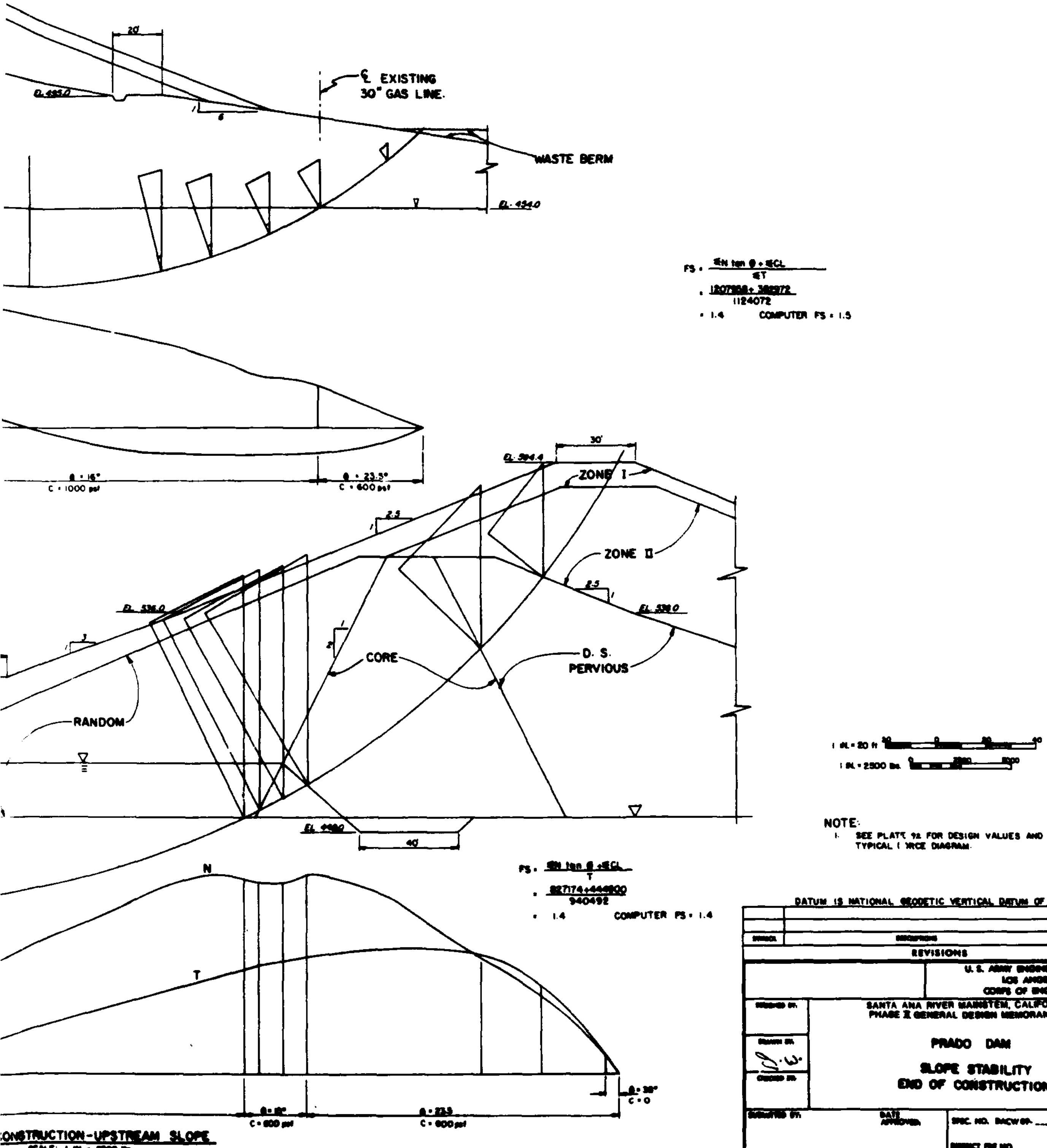


END OF CONSTRUCTION DOWNSTREAM SLOPE



END OF CONSTRUCTION-UPSTREAM SLOPE

SCALE: 1 in. = 2000 lbs.



$$FS = \frac{\Sigma N \tan \phi + \Sigma CL}{\Sigma T}$$

$$= \frac{1207908 + 389972}{1124072}$$

$$= 1.4 \qquad \text{COMPUTER } FS = 1.5$$

$$FS = \frac{\Sigma N \tan \phi + \Sigma CL}{T}$$

$$= \frac{827174 + 446900}{940492}$$

$$= 1.4 \qquad \text{COMPUTER } FS = 1.4$$

ONSTRUCTION-UPSTREAM SLOPE

SCALE: 1 IN. = 2500 lbs.

NOTE:

1. SEE PLATE 92 FOR DESIGN VALUES AND TYPICAL FORCE DIAGRAM.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SLOPE STABILITY
END OF CONSTRUCTION

DESIGNED BY:

DRAWN BY: J.W.

CHECKED BY:

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09- ___ B- ___

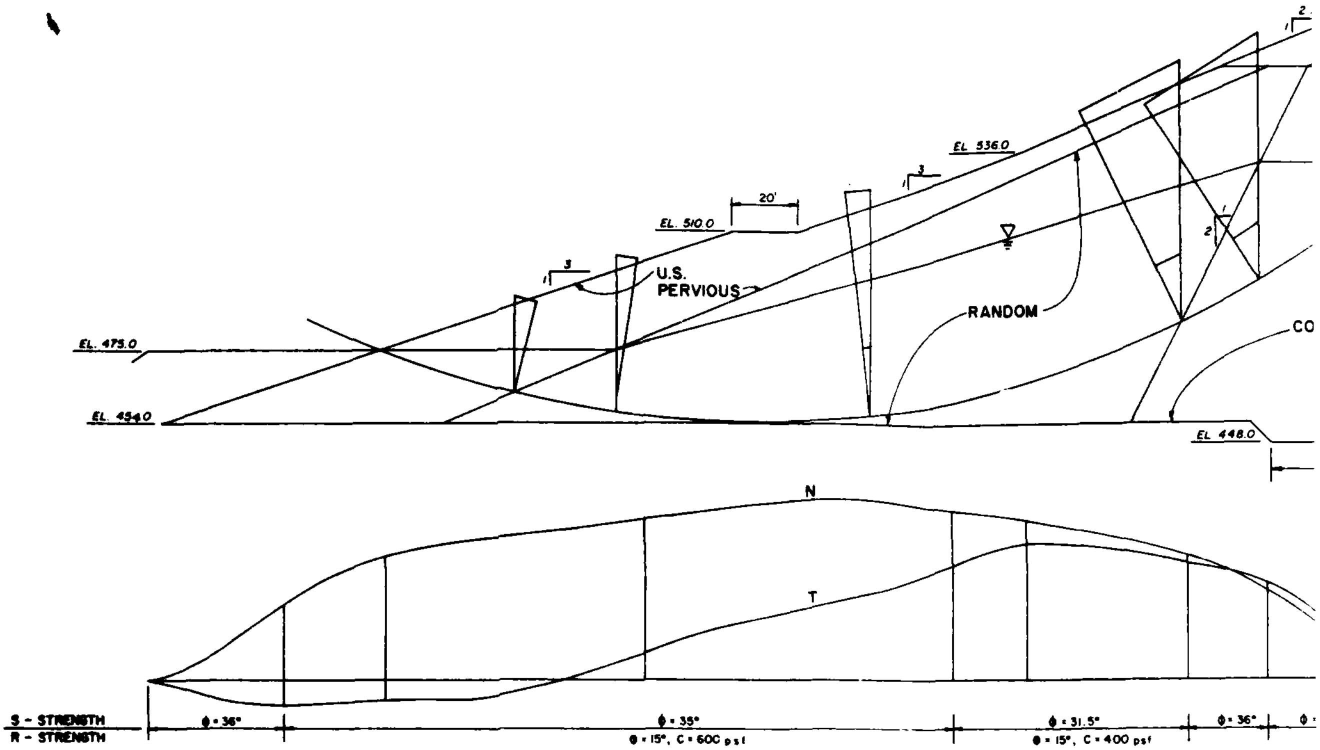
DISTRICT FILE NO.

SHEET

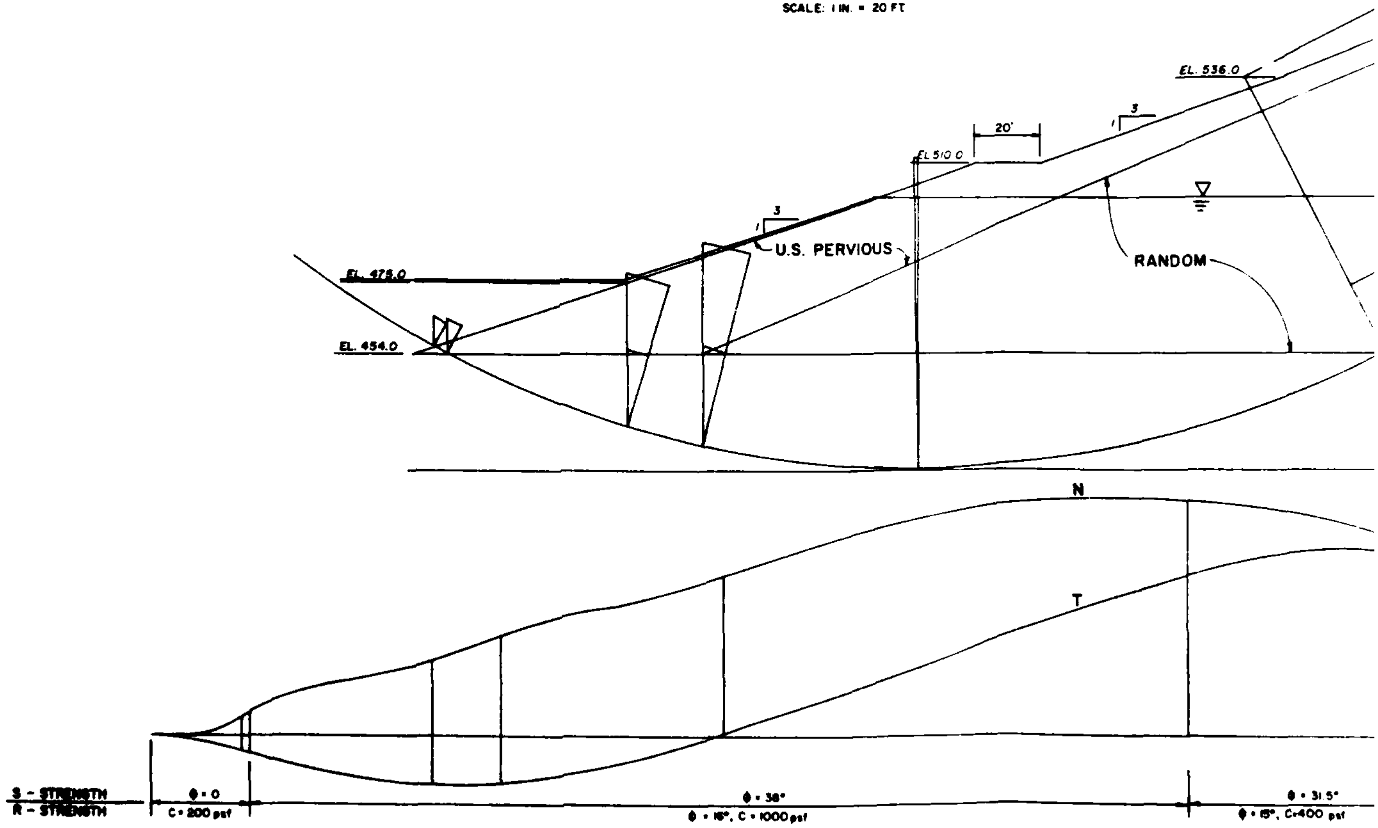
PLATE B-93

1

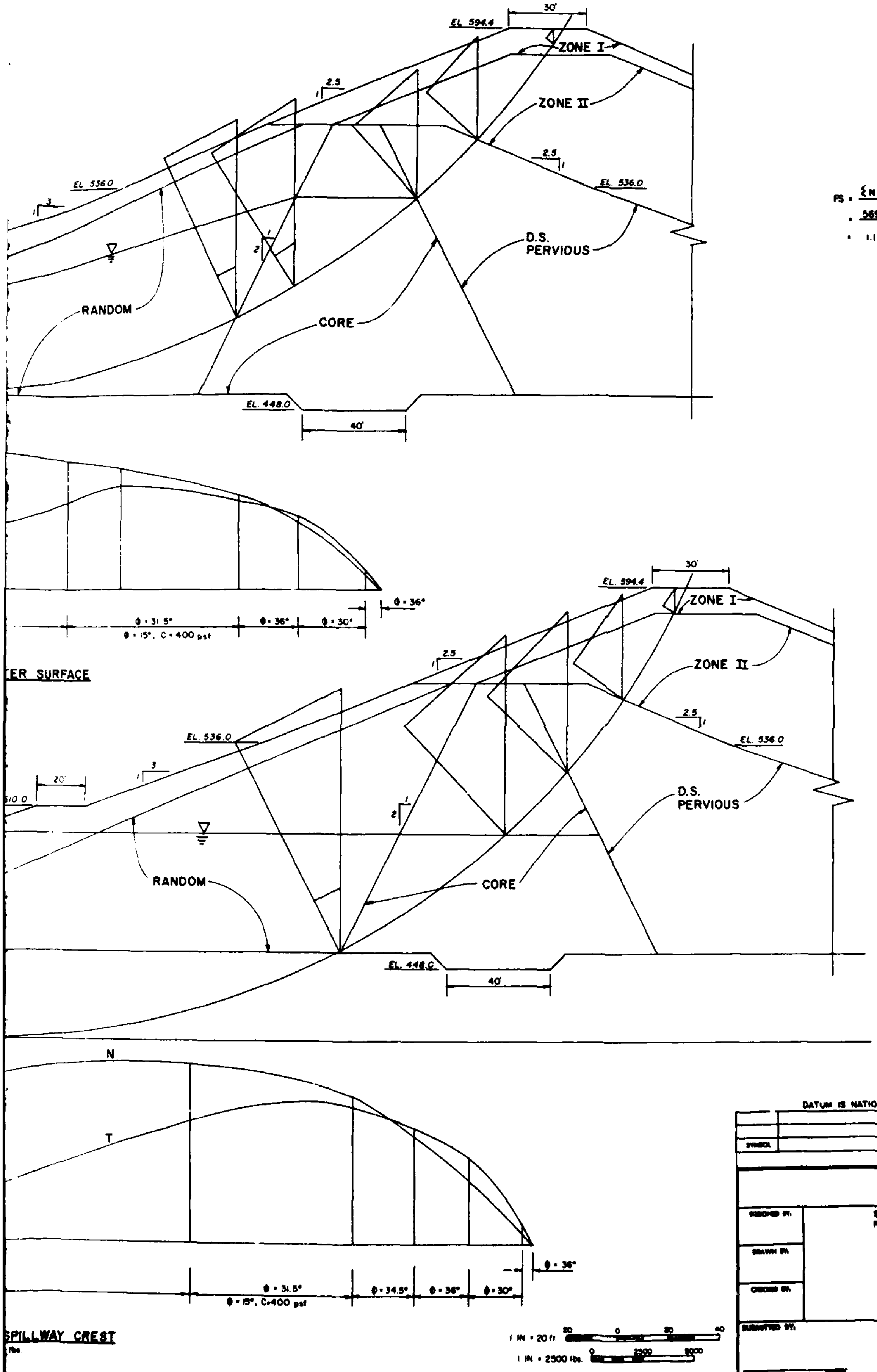
2



SUDDEN DRAWDOWN FROM MAX. WATER SURFACE
SCALE: 1 IN. = 20 FT



SUDDEN DRAWDOWN FROM SPILLWAY CREST
SCALE: 1 IN. = 2500 lbs



$$FS = \frac{\Sigma N \tan \phi + \Sigma CL}{\Sigma T} = \frac{569587 + 136000}{669926} = 1.1$$

MINIMUM COMPUTER FS = 1.0

$$FS = \frac{\Sigma N \tan \phi + \Sigma CL}{\Sigma T} = \frac{773261 + 324400}{947981} = 1.2$$

MINIMUM COMPUTER FS = 1.2

NOTES:

1. SEE PLATE 92 FOR DESIGN VALUES AND TYPICAL FORCE DIAGRAM.
2. COMBINED R-S SHEAR STRENGTHS WERE USED WHERE R, S STRENGTHS ARE INDICATED.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SLOPE STABILITY
SUDDEN DRAWDOWN

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW 09-____ B-____

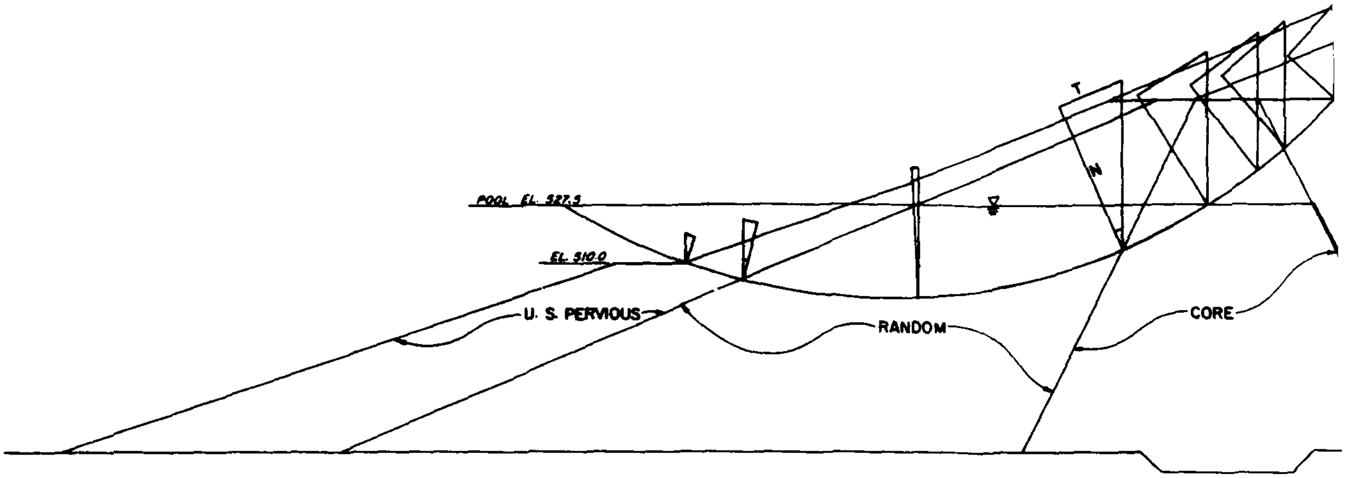
DISTRICT FILE NO.

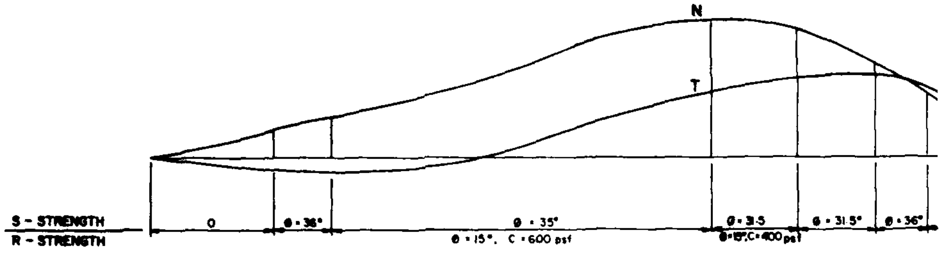
SHEET

PLATE B-94

1

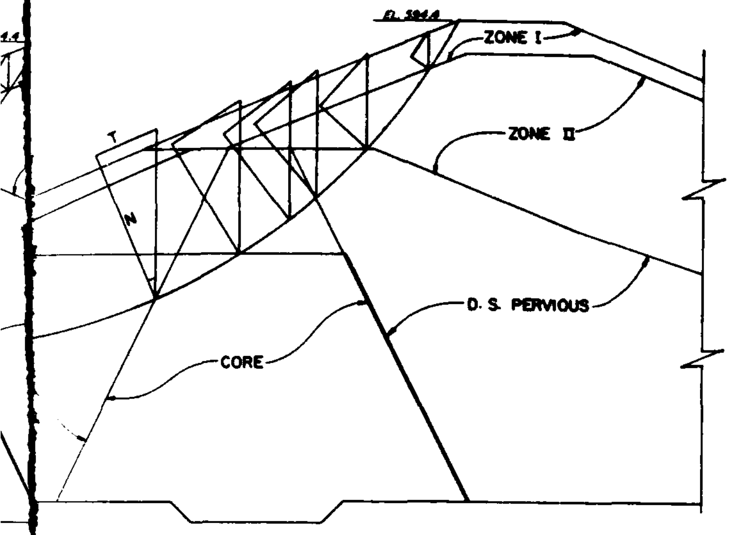
2

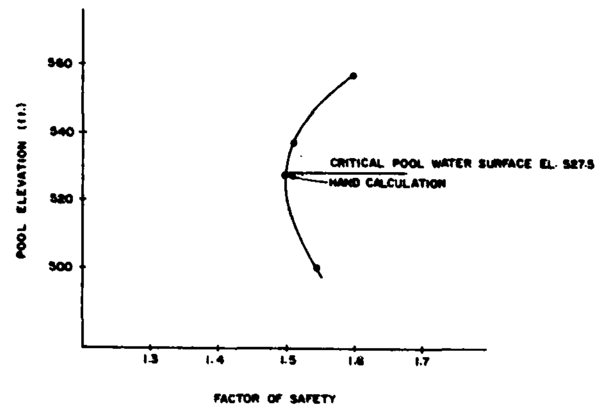


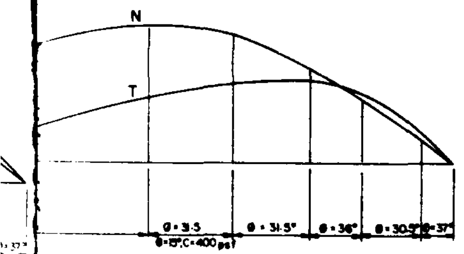


PARTIAL POOL
SCALE - 1 IN. = 2500 lbs

UE ENGINEERING PAYS







$$FS = \frac{\Sigma N \tan\theta + \Sigma CL}{\Sigma T}$$

$$= \frac{364416 + 40527}{270566}$$

$$= 1.5$$

NOTE:

1. SEE PLATE 92 FOR DESIGN VALUES AND TYPICAL FORCE DIAGRAM.
2. (R+S)/2 STRENGTHS USED WHERE R & S STRENGTHS ARE SHOWN.

1 IN. = 20 ft. 20 0 20 40

1 IN. = 2500 lbs. 0 2500 5000

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SLOPE STABILITY
PARTIAL POOL

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

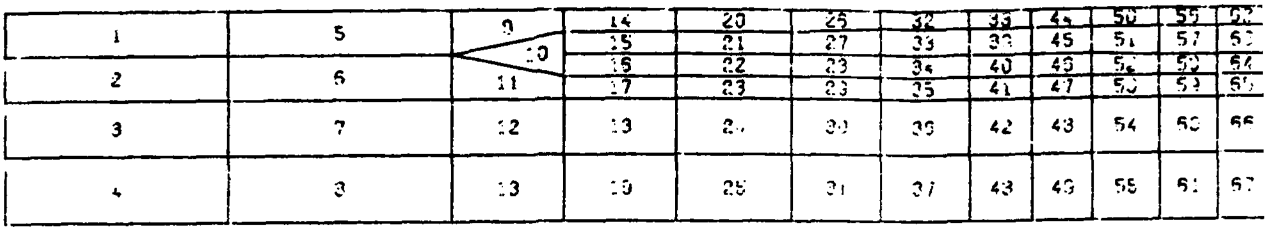
DISTRICT FILE NO.

SHEET

PLATE B-66

SAFETY PAYS

2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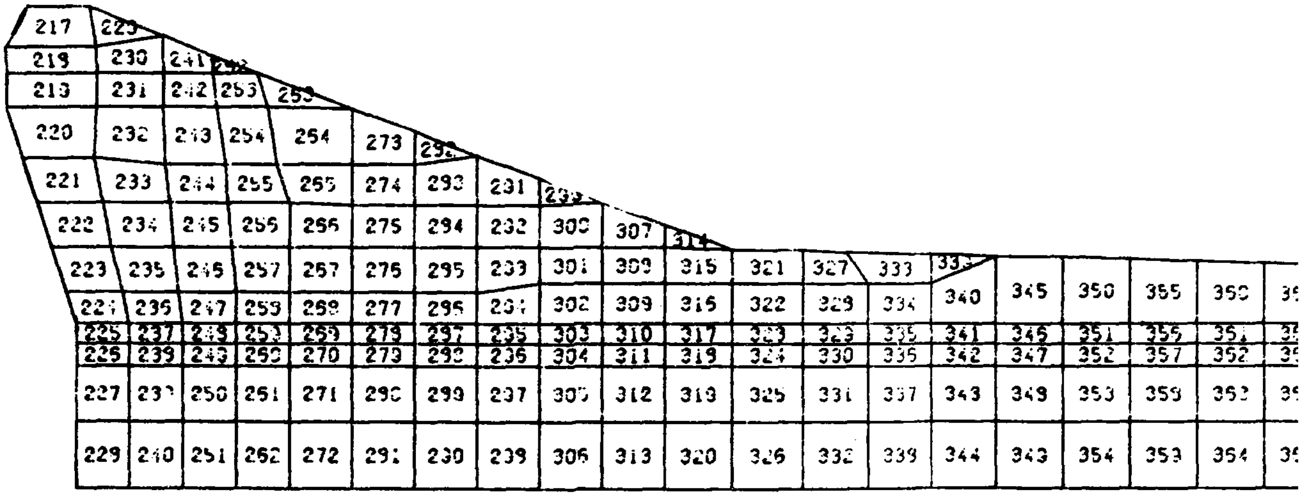
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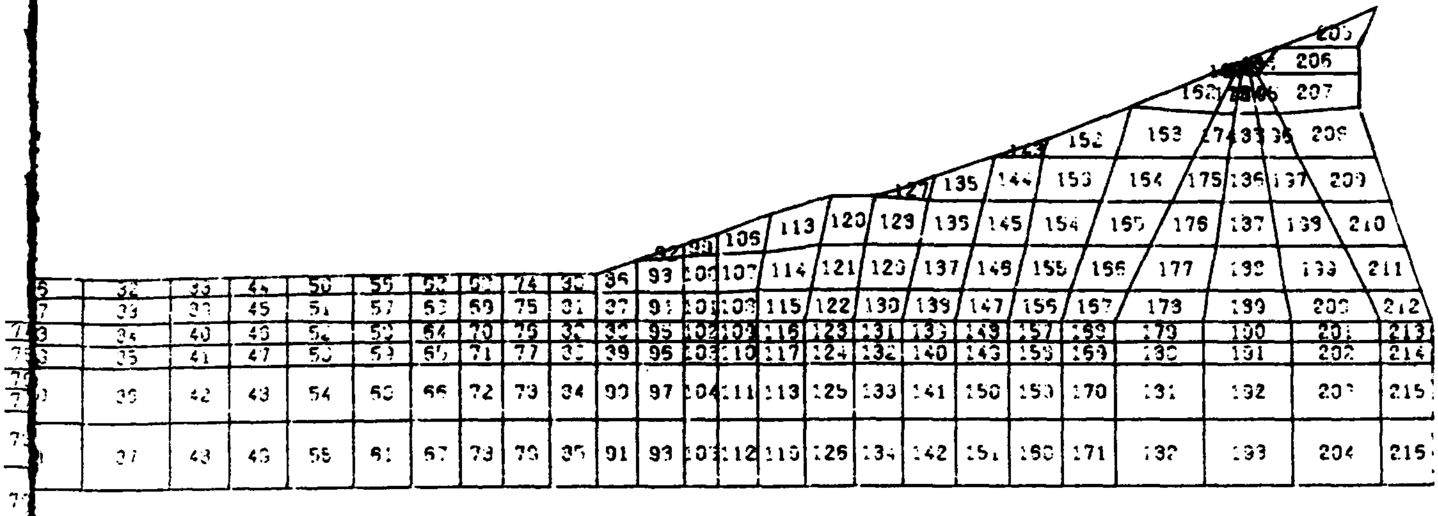
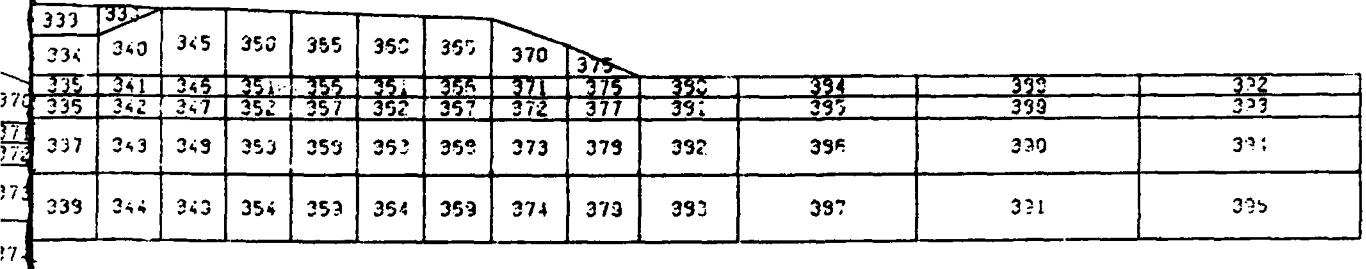




SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FINITE ELEMENT MESH

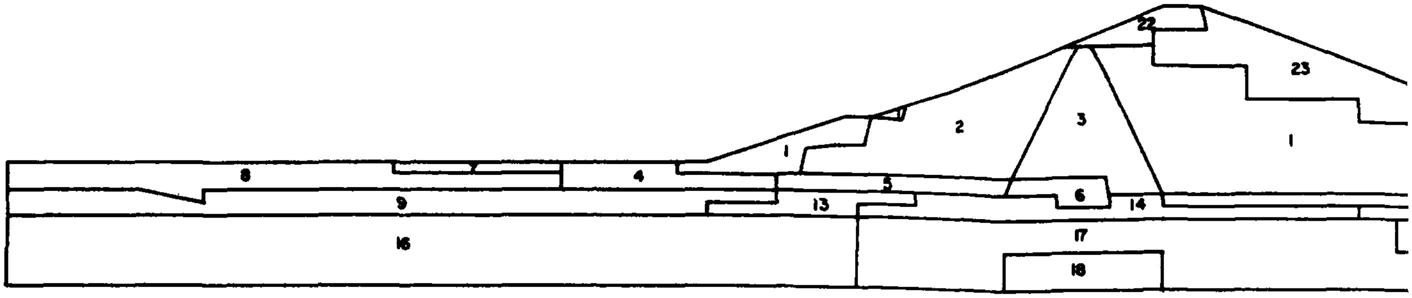
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-
DISTRICT FILE NO.
SHEET
OF

PLATE B-96

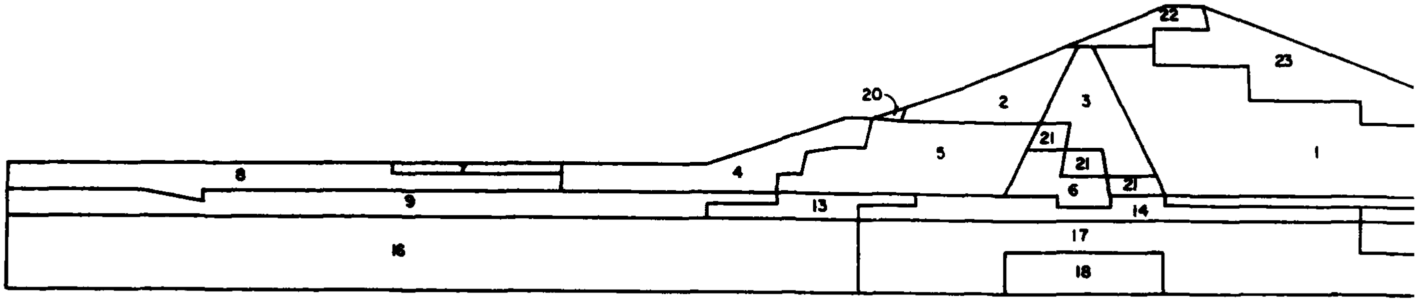
1

2

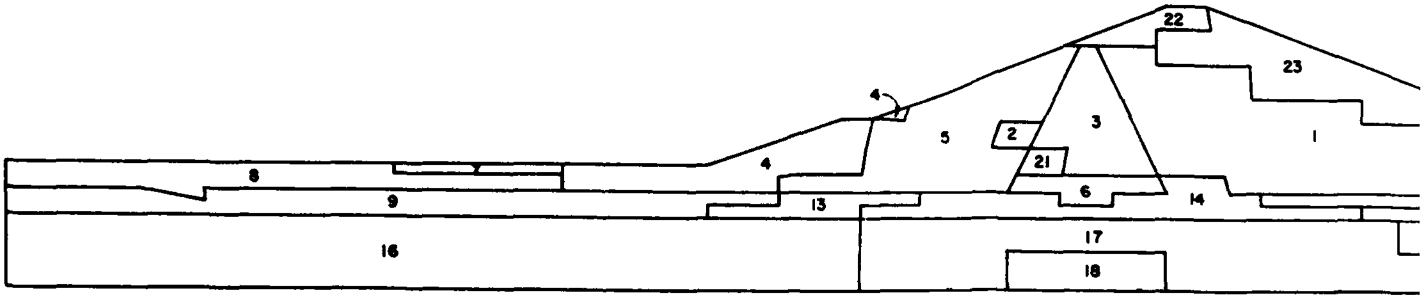
VALUE ENGINEERING PA



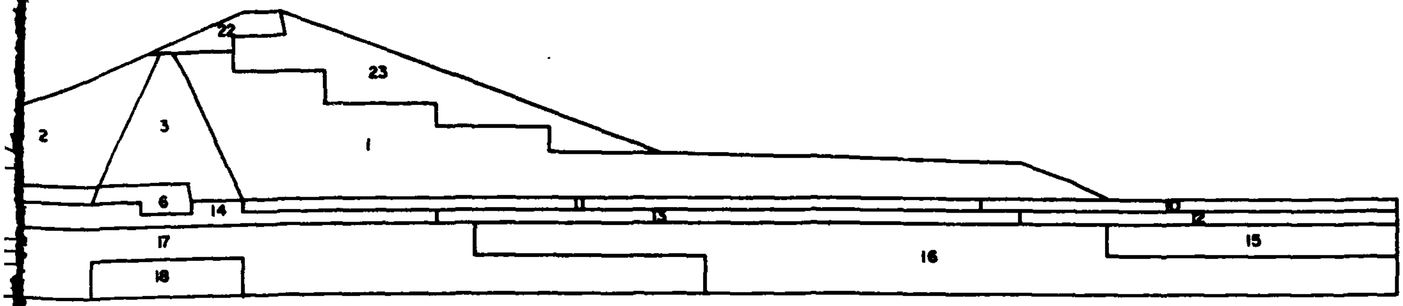
STATIC FEM MATERIAL PROPERTIES FOR POOL E



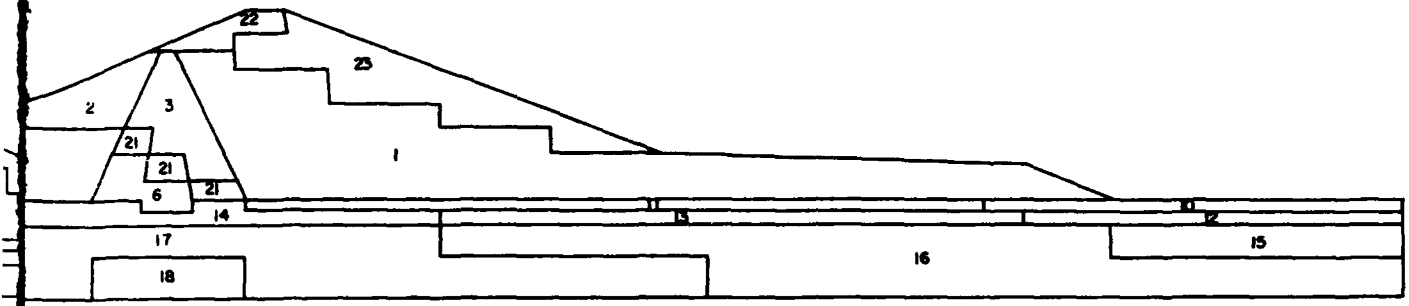
STATIC FEM MATERIAL PROPERTIES FOR POOL @ EL.



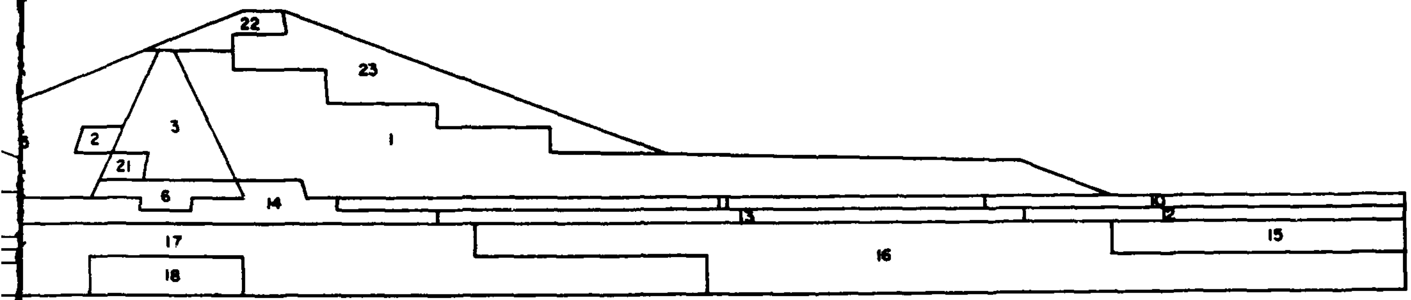
STATIC FEM MATERIAL PROPERTIES FOR FLOOD POOL



FEM MATERIAL PROPERTIES FOR POOL EMPTY



FEM MATERIAL PROPERTIES FOR POOL @ EL. 500



MATERIAL PROPERTIES FOR FLOOD POOL @ EL. 562.9

NOTES:

1. SEE TABLE 28 FOR STATIC MATERIAL PROPERTY VALUES.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYM.	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

STATIC FINITE ELEMENT MESH
MATERIAL PROPERTIES

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

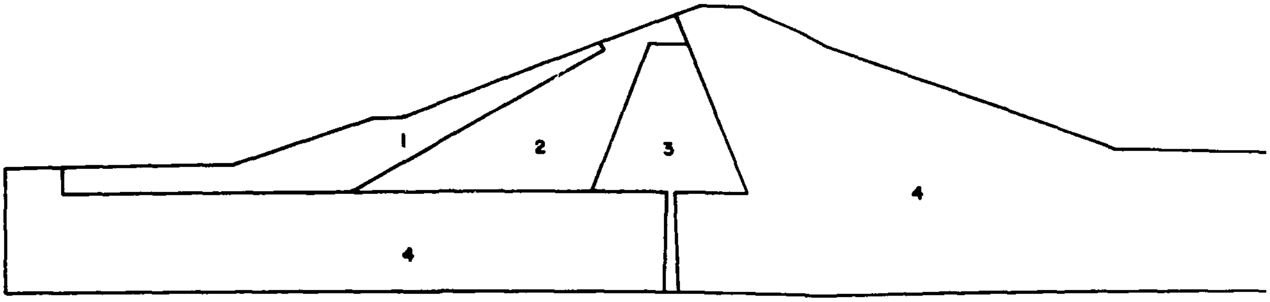
SHEET

PLATE B-67

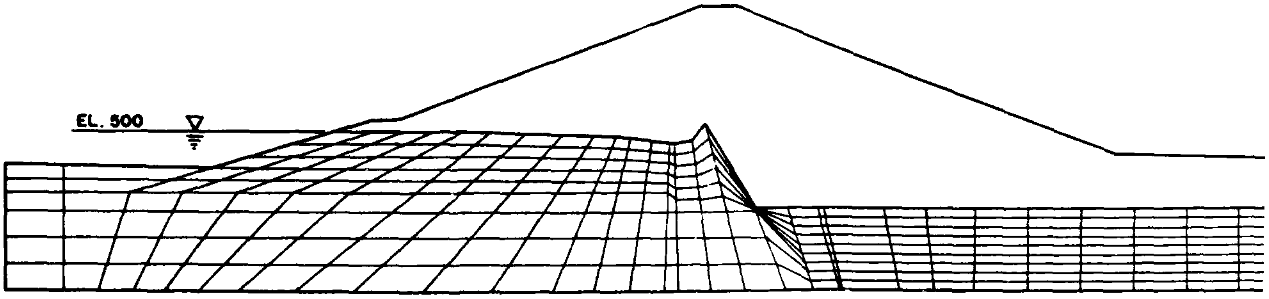
1

2

VALUE ENGINEERING PAY

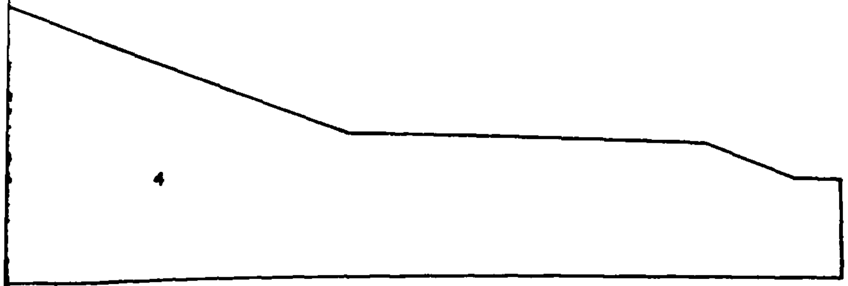


FEM SEEPAGE MATERIAL PERMEABILITY



TYPICAL FEM SEEPAGE MESH

SAFETY PAYS

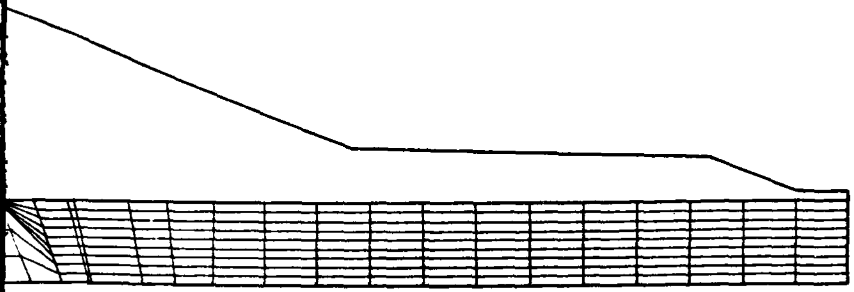


MATERIAL PERMEABILITY

MATERIAL NUMBER	PERMEABILITY FEET/DAY	
	HORIZONTAL	VERTICAL
1	1000	500
2	0.01	0.001
3	0.003	0.0003
4	300	30

NOTE:

1. PERMEABILITIES FOR EMBANKMENT MATERIALS 1, 2, 3, AND 4 WERE OBTAINED FROM PRADO MODEL STUDY (DEC. 1988)



FEM SEEPAGE MESH

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

TYPICAL FEM SEEPAGE MESH
AND MATERIAL PROPERTIES

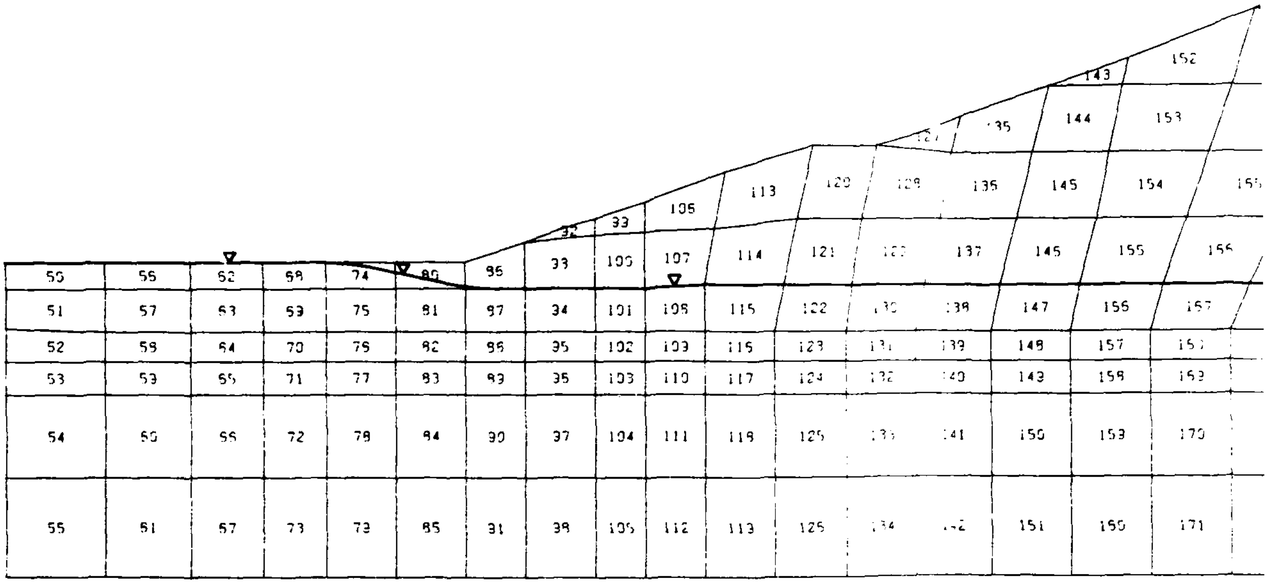
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW 09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-60

1

2

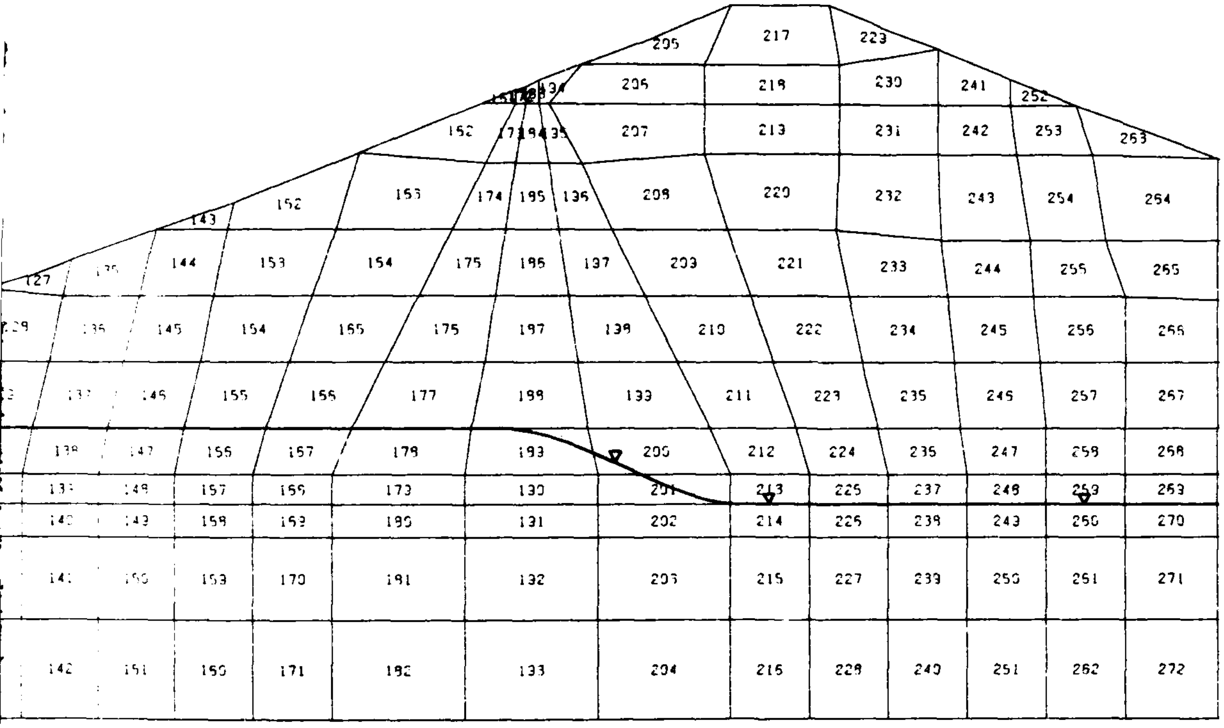
VALUE ENGINEERIN



PHREATIC SURFACE

SAFETY PA

VALUE ENGINEERING PAYS



PHREATIC SURFACE

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

POOL EMPTY PHREATIC SURFACE

SPEC. NO. DACW09- ___ B- ___

DISTRICT FILE NO.

PLATE [illegible]

SAFETY PAYS

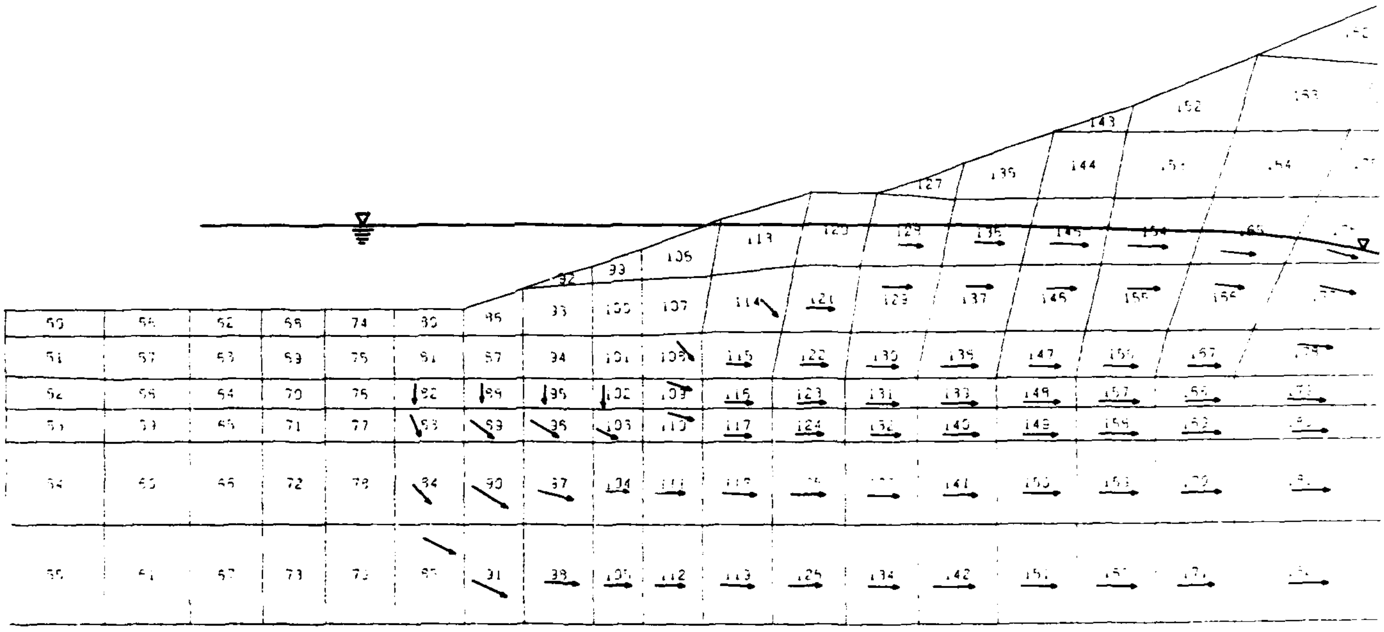
1

2

ELEMENT	HYDRAULIC GRADIENT
82	.012
83	.012
84	.012
85	.012
88	.013
89	.013
90	.013
91	.012
95	.014
96	.014
97	.014
98	.013
102	.017
103	.017
104	.017
105	.014
106	.020
108	.020
110	.020
111	.017
112	.017
114	.025
115	.020
116	.020
117	.020
118	.020
119	.012
121	.025
122	.025
123	.020
124	.020
125	.015
126	.012
128	.030
129	.033
130	.025
131	.025
132	.020
133	.015
134	.012

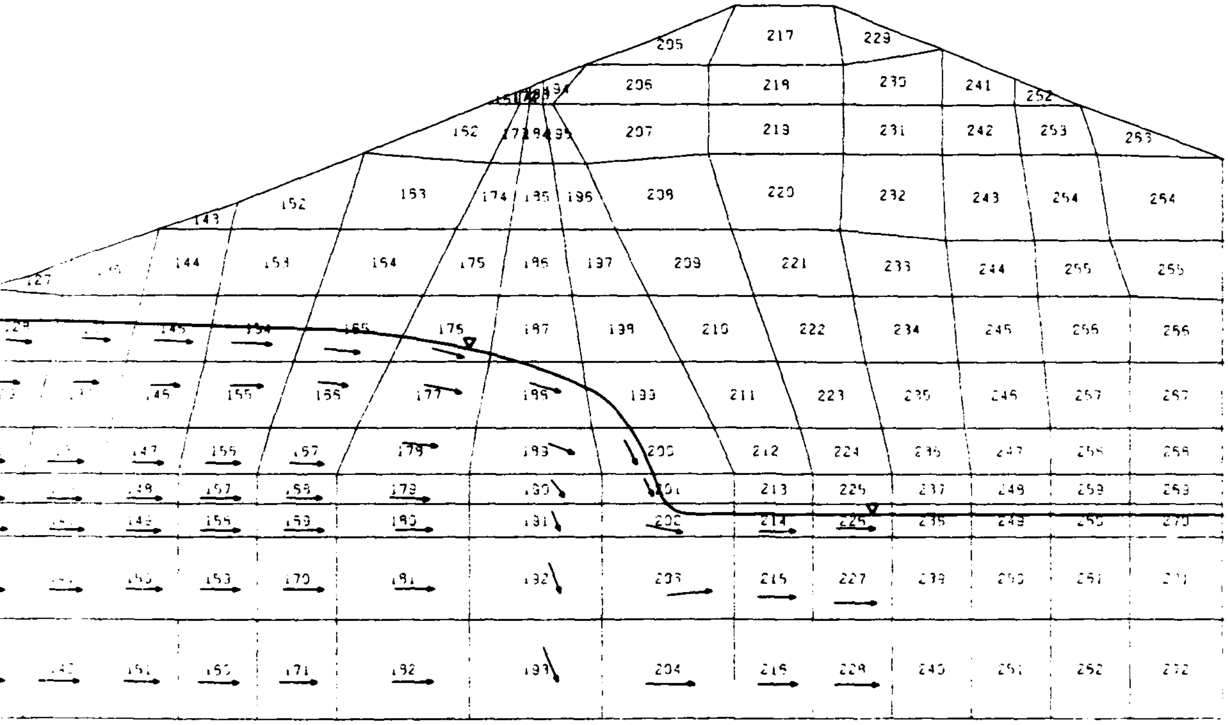
ELEMENT	HYDRAULIC GRADIENT
136	.050
137	.030
138	.025
139	.025
140	.030
141	.018
142	.012
143	.030
146	.030
147	.025
148	.033
149	.029
150	.028
151	.025
154	.033
155	.033
156	.033
157	.033
158	.033
159	.033
160	.033
165	.067
166	.067
167	.067
168	.067
169	.067
170	.067
171	.067
176	.251
177	.200
178	.167
179	.167
180	.167
181	.167
182	.167
188	.300
189	.237
190	.225
191	.225
192	.740

ELEMENT	HYDRAULIC GRADIENT
193	.740
200	.740
201	.740
202	.740
203	.033
204	.033
214	.002
215	.002
216	.002
226	.001
227	.001
228	.001



SEEPAGE FORCES

VALUE ENGINEERING PAYS



SEEPAGE FORCES

NOTE
ARROWS INDICATE THE DIRECTION OF SEEPAGE FORCES.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

POOL, EL. 500
SEEPAGE FORCES

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___-B-___
SHEET
DISTRICT FILE NO.

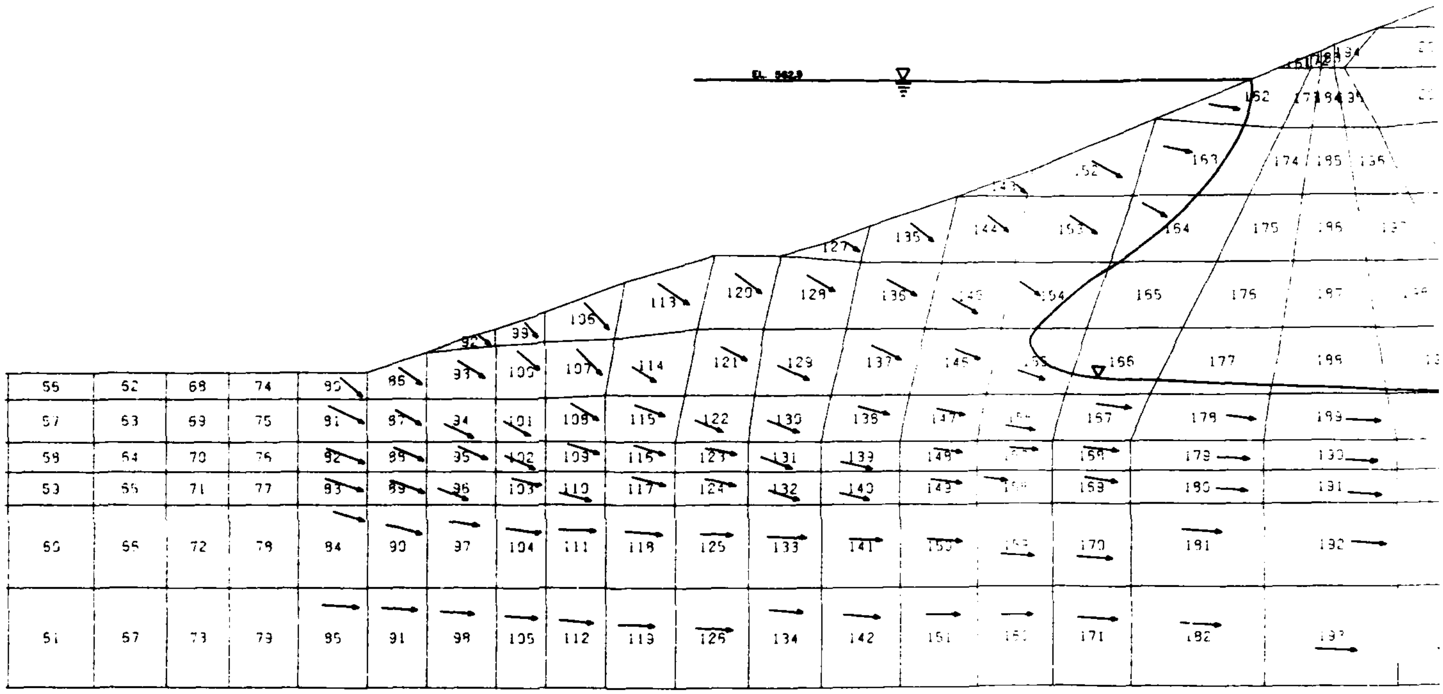
PLATE B-100

SAFETY PAYS

1

2

ELEMENT	HYDRAULIC GRADIENT	ELEMENT	HYDRAULIC GRADIENT	ELEMENT	HYDRAULIC GRADIENT	ELEMENT	HYDRAULIC GRADIENT
80	.125	121	.513	162	.286	260	.009
81	.125	122	.250	163	.333	261	.009
82	.125	123	.182	164	.370	262	.009
83	.125	124	.125	167	.176	270	.009
84	.268	125	.087	168	.176	271	.009
85	.087	126	.087	169	.176	272	.009
86	.125	127	.400	170	.176		
87	.125	128	.513	171	.176		
88	.125	129	.513	178	.035		
89	.125	130	.200	179	.035		
90	.268	131	.182	180	.035		
91	.087	132	.125	181	.035		
92	.182	133	.123	182	.035		
93	.182	134	.087	189	.035		
94	.125	135	.400	190	.035		
95	.125	136	.400	191	.035		
96	.125	137	.513	192	.035		
97	.176	138	.268	193	.035		
98	.087	139	.268	200	.052		
99	.250	140	.176	201	.052		
100	.182	141	.087	202	.052		
101	.125	142	.087	203	.052		
102	.125	143	.370	204	.052		
103	.125	144	.370	212	.105		
104	.176	145	.400	213	.105		
105	.087	146	.513	214	.105		
106	.250	147	.176	215	.105		
107	.250	148	.141	216	.105		
108	.182	149	.123	224	.277		
109	.125	150	.087	225	.277		
110	.125	151	.052	226	.277		
111	.087	152	.333	227	.277		
112	.087	153	.370	228	.277		
113	.513	154	.400	237	.194		
114	.250	155	.513	238	.194		
115	.250	156	.176	239	.194		
116	.182	157	.087	240	.194		
117	.125	158	.087	249	.123		
118	.087	159	.087	250	.123		
119	.087	160	.052	251	.123		
120	.513	161					

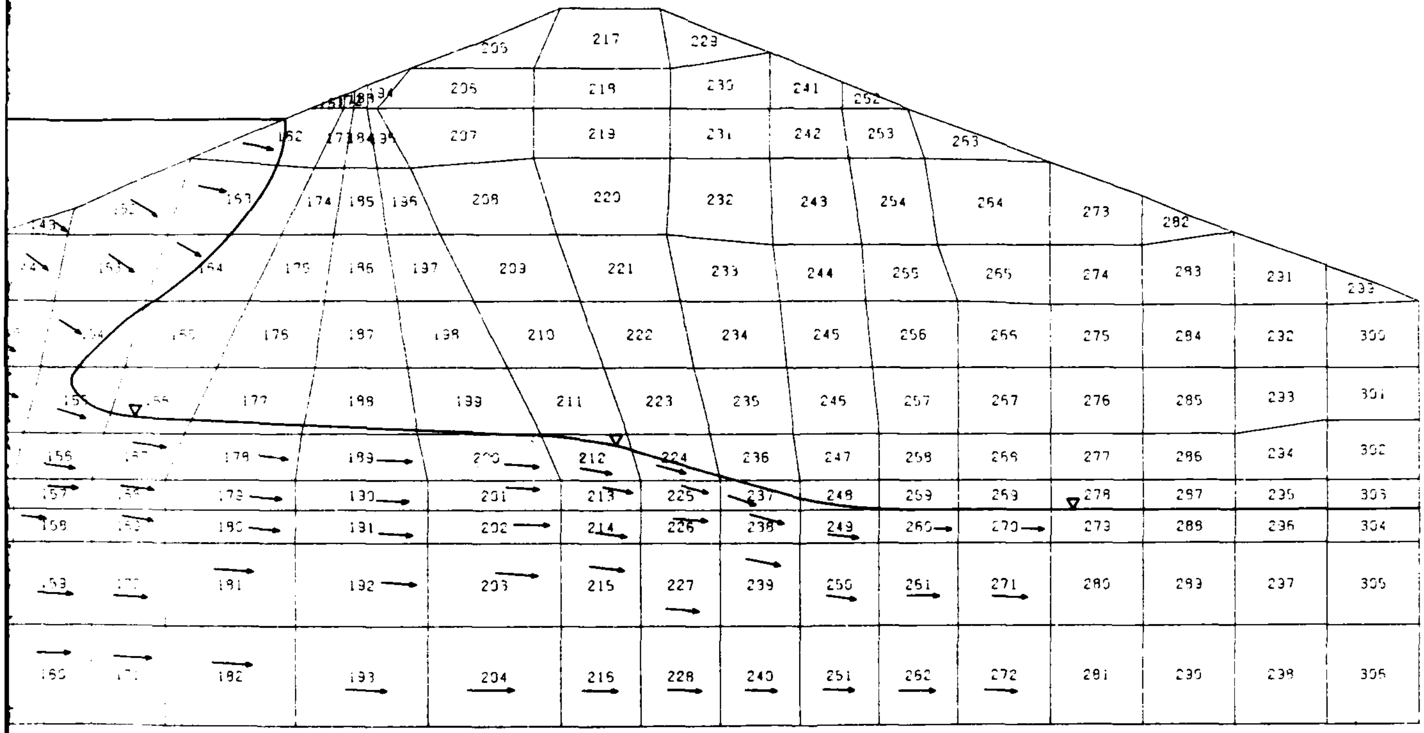


SEEPAGE FORCES

NOT

VALUE ENGINEERING PAYS

ELEMENT	HYDRAULIC GRADIENT
260	.009
261	.009
262	.009
270	.009
271	.009
272	.009



SEEPAGE FORCES

NOTE

ARROWS INDICATE THE DIRECTION OF SEEPAGE FORCES.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FLOOD POOL, EL. 562.9
SEEPAGE FORCES

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

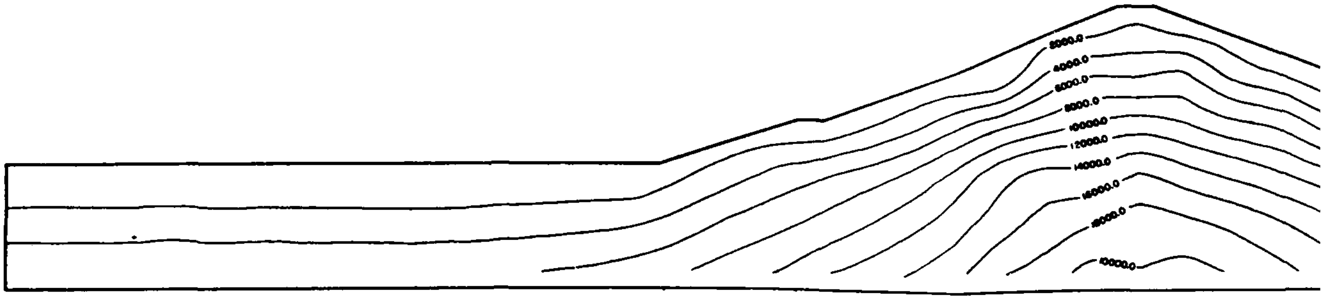
SHEET

PLATE B-161

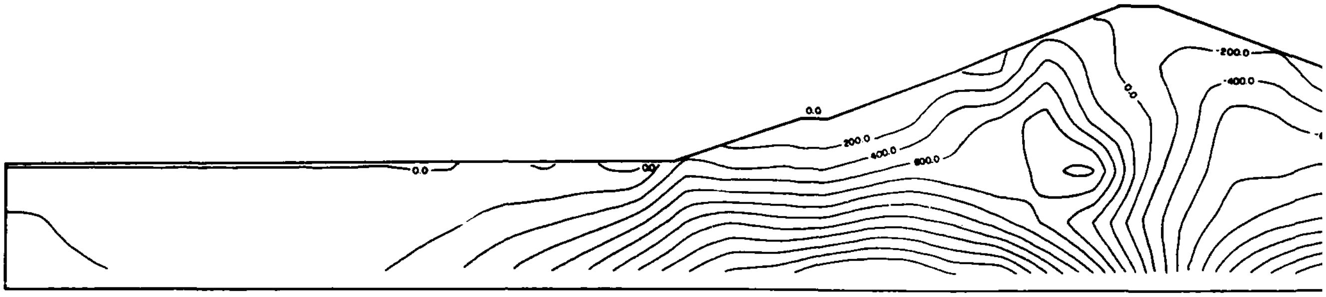
SAFETY PAYS

1

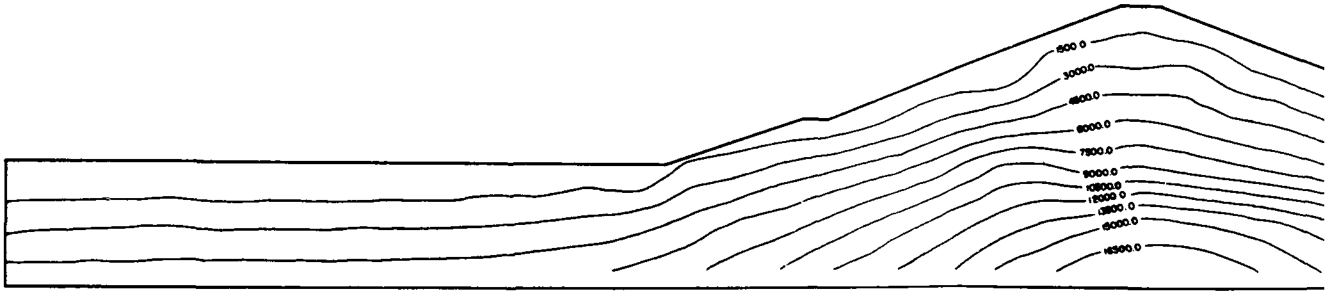
2



σ_x' (PSF)

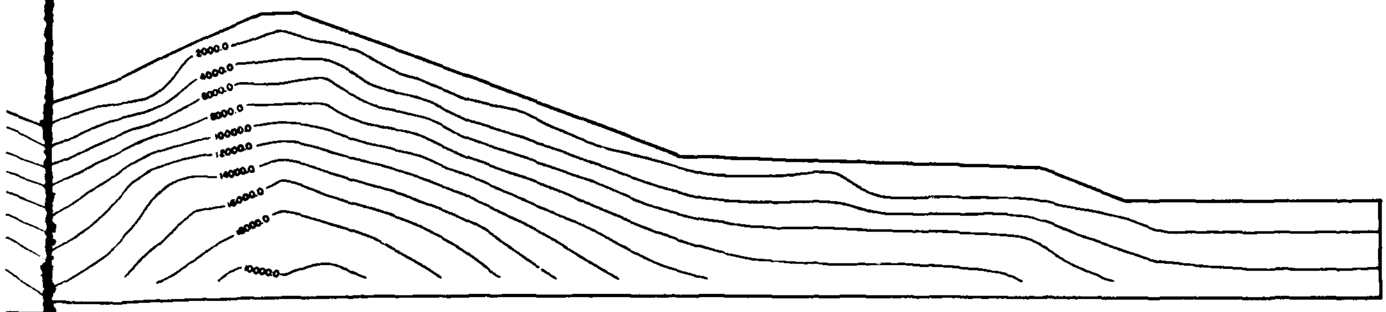


τ_{xy}' (PSF)

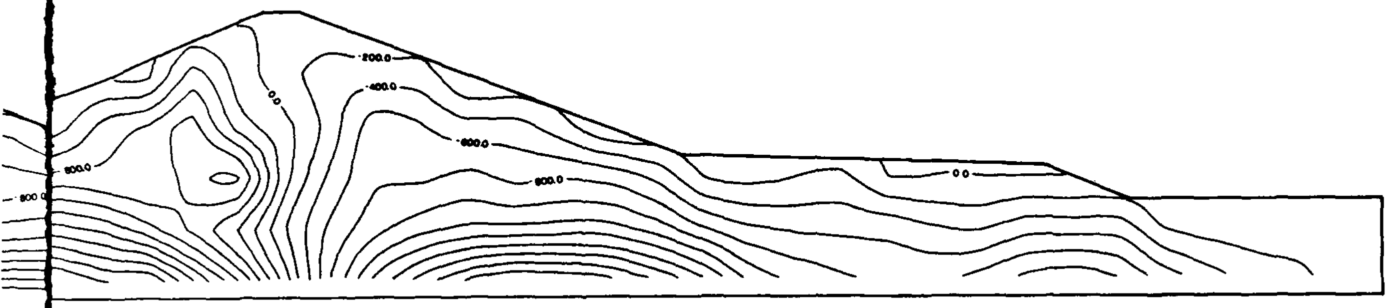


σ_m' (PSF)

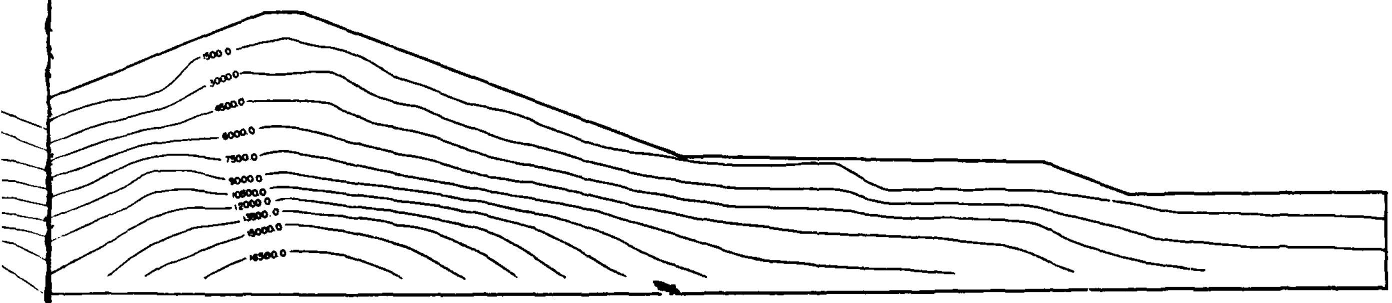
STATIC STRESSES FOR POOL EMPTY



σ_x' (PSF)



τ_{xy}' (PSF)



σ_m' (PSF)

STATIC STRESSES FOR POOL EMPTY

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
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CORPS OF ENGINEERS

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PHASE II GENERAL DESIGN MEMORANDUM

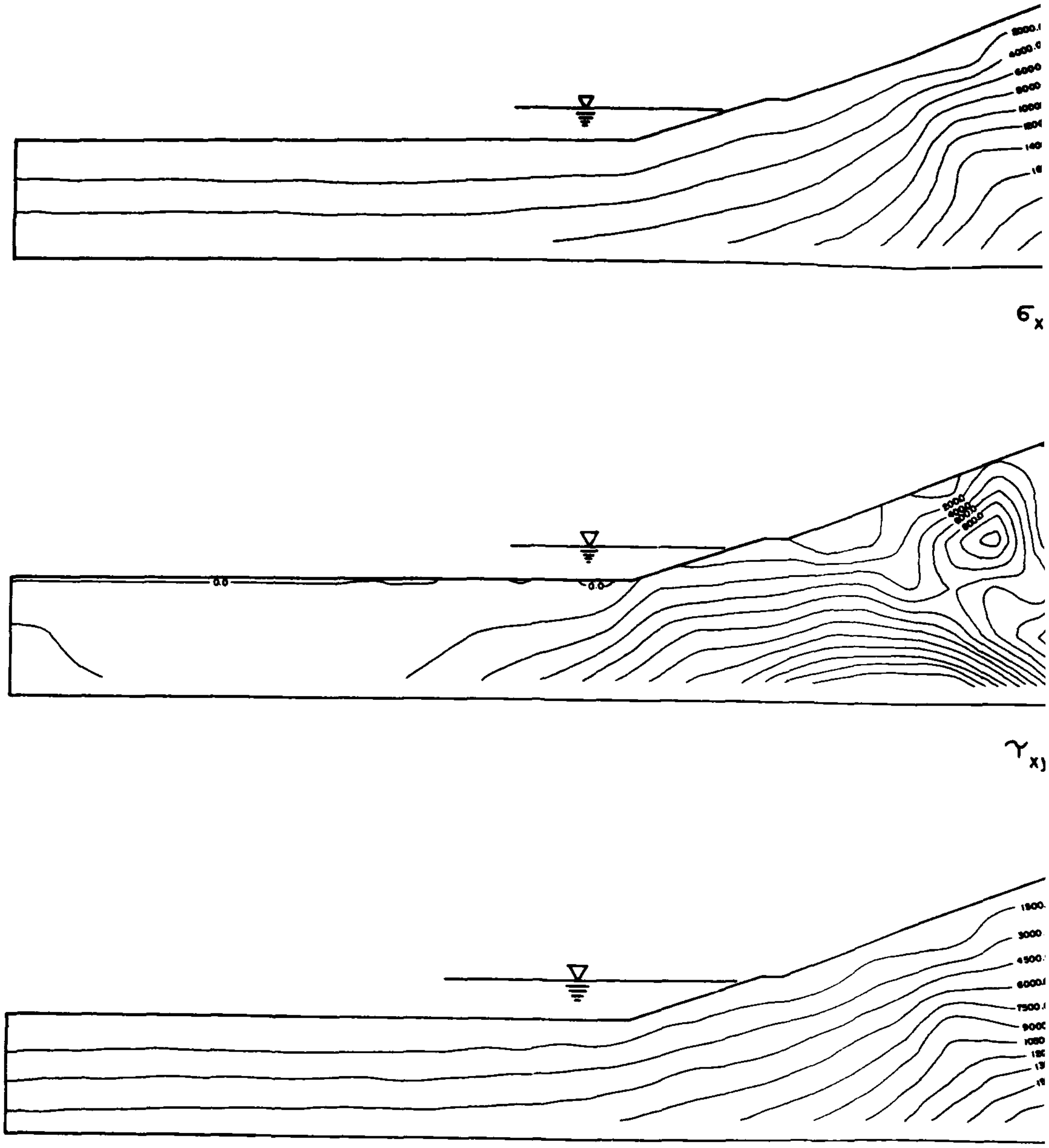
PRADO DAM

POOL EMPTY, CONTOUR PLOT
OF σ_x', σ_m', τ_{xy}'

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET

PLATE B-102

VALUE EI



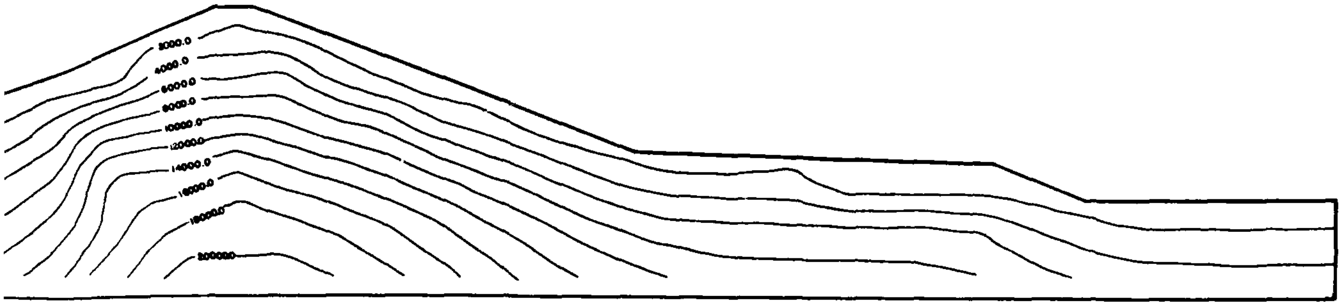
σ_x

τ_{xy}

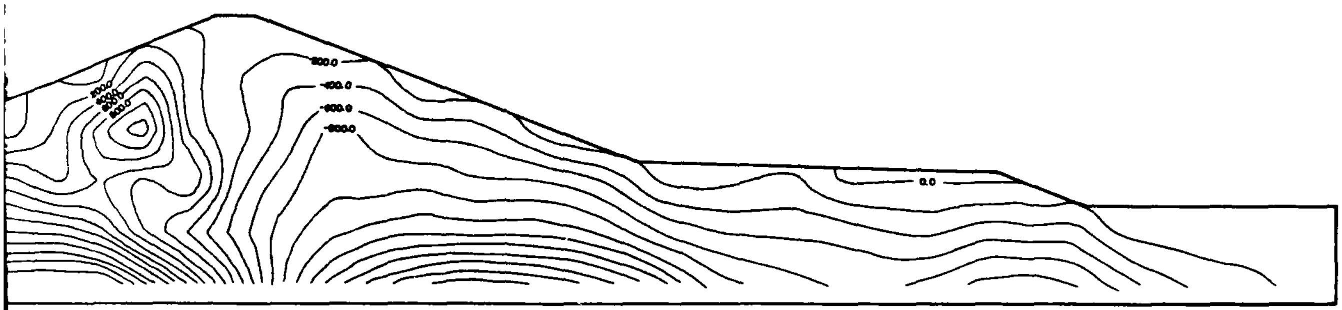
σ_m'

STATIC STRESSE

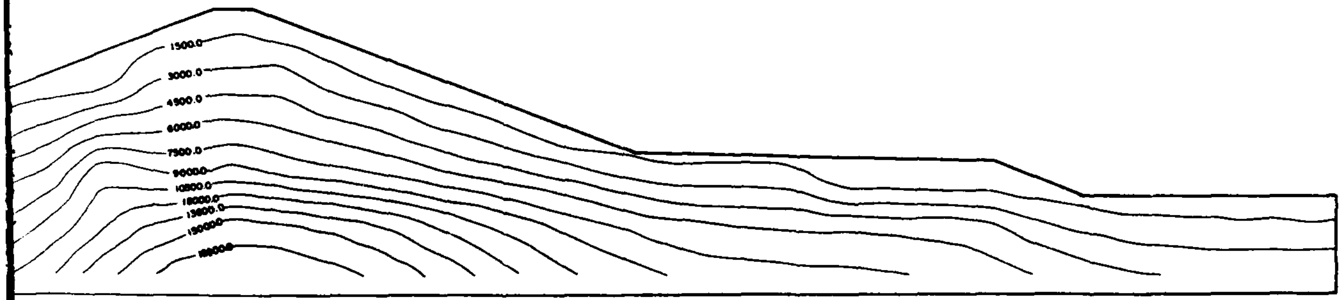
SAF



σ_x' (PSF)



τ_{xy}' (PSF)



σ_m' (PSF)

STATIC STRESSES FOR POOL @ EL. 500

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

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LOS ANGELES
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PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

POOL, EL. 500, CONTOUR
PLOT OF σ_x', σ_m', τ_{xy}'

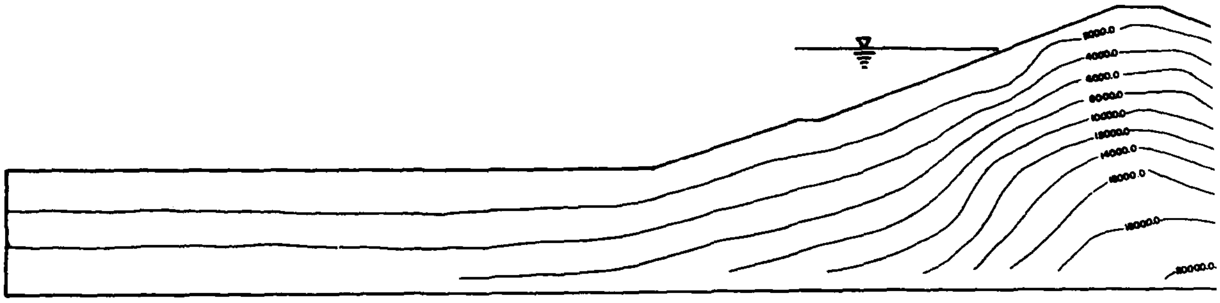
SUBMITTED BY
DATE APPROVED
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-100

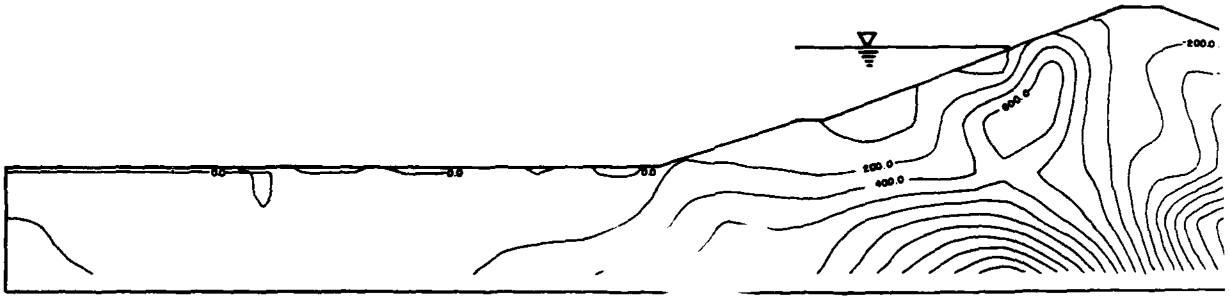
1

2

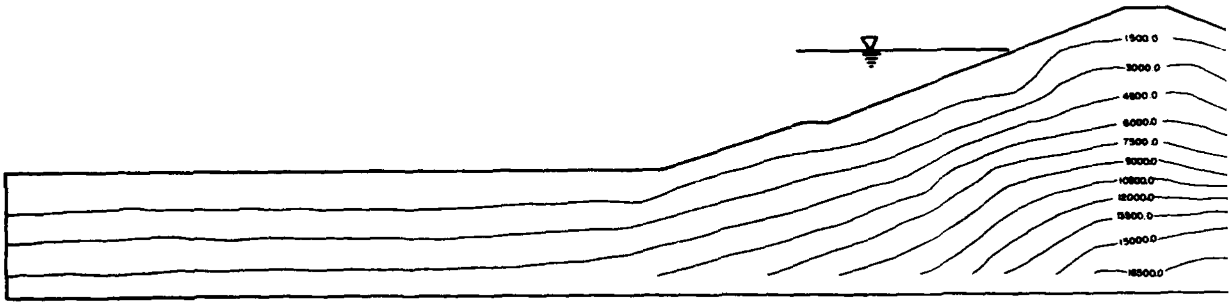
VALUE ENGINEE



σ_x' (PSF)



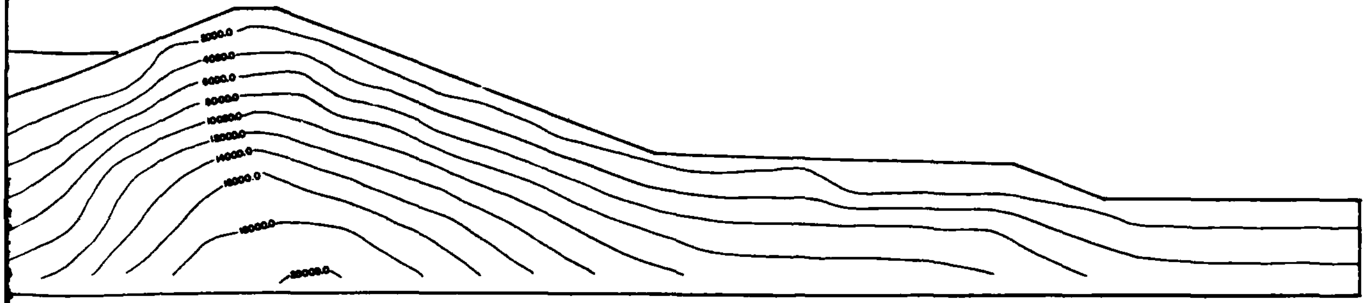
τ_{xy}' (PSF)



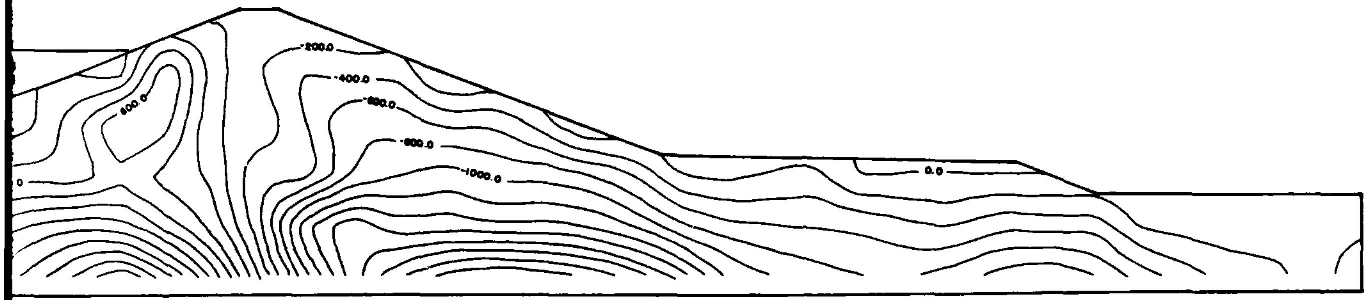
σ_m' (PSF)

STATIC STRESSES FOR FLOOD P

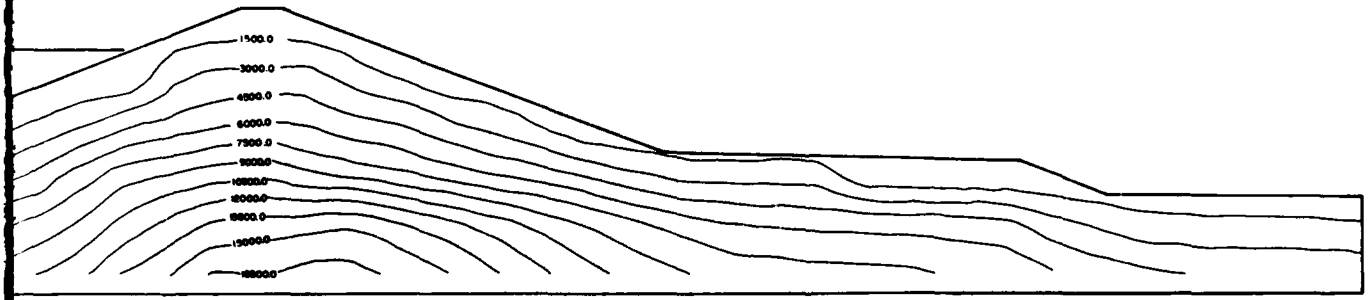
SAFETY P



σ_x' (PSF)



γ_{xy}' (PSF)



σ_m' (PSF)

TATIC STRESSES FOR FLOOD POOL @ EL. 562.9

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

FLOOD POOL, EL. 562.9 CONTOUR
PLOT OF σ_x', σ_m', γ_{xy}'

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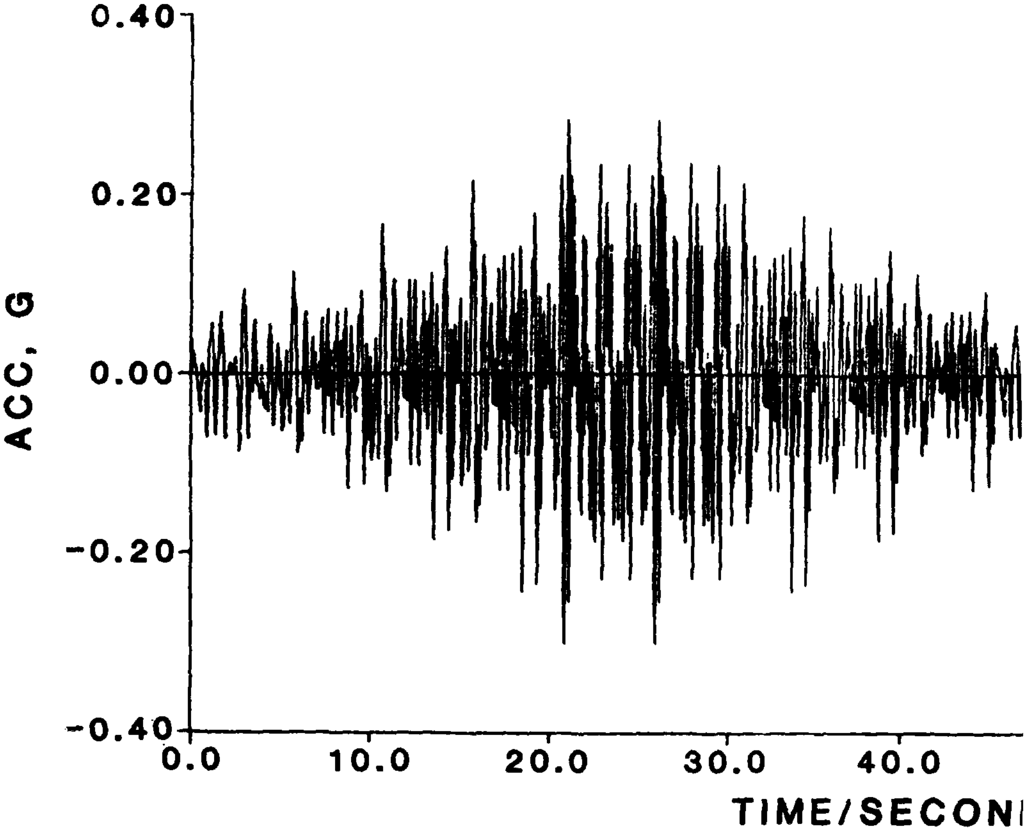
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-104

1

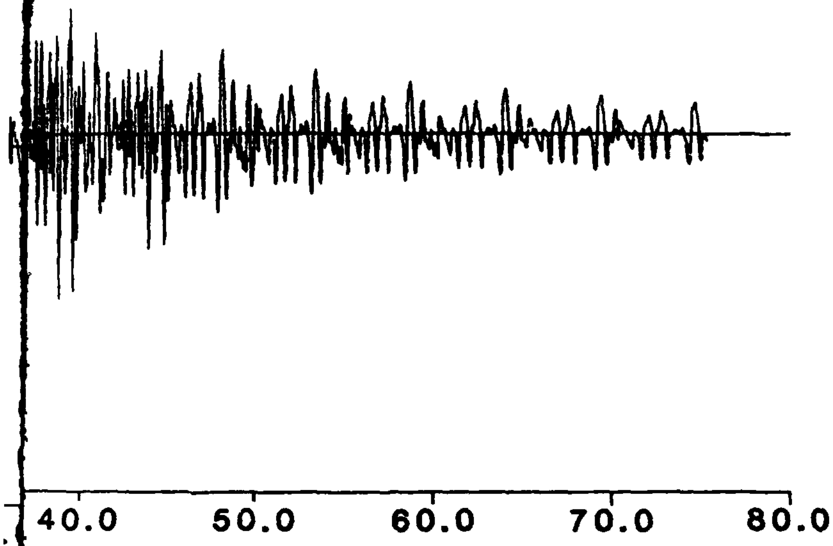
2

U. S. ARMY ENGINEER DISTRICT



SEED-IDRISS 8+ MAG RECORD

CORPS OF ENGINEERS



CORD SCALED TO 0.30 MAX

REVISIONS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

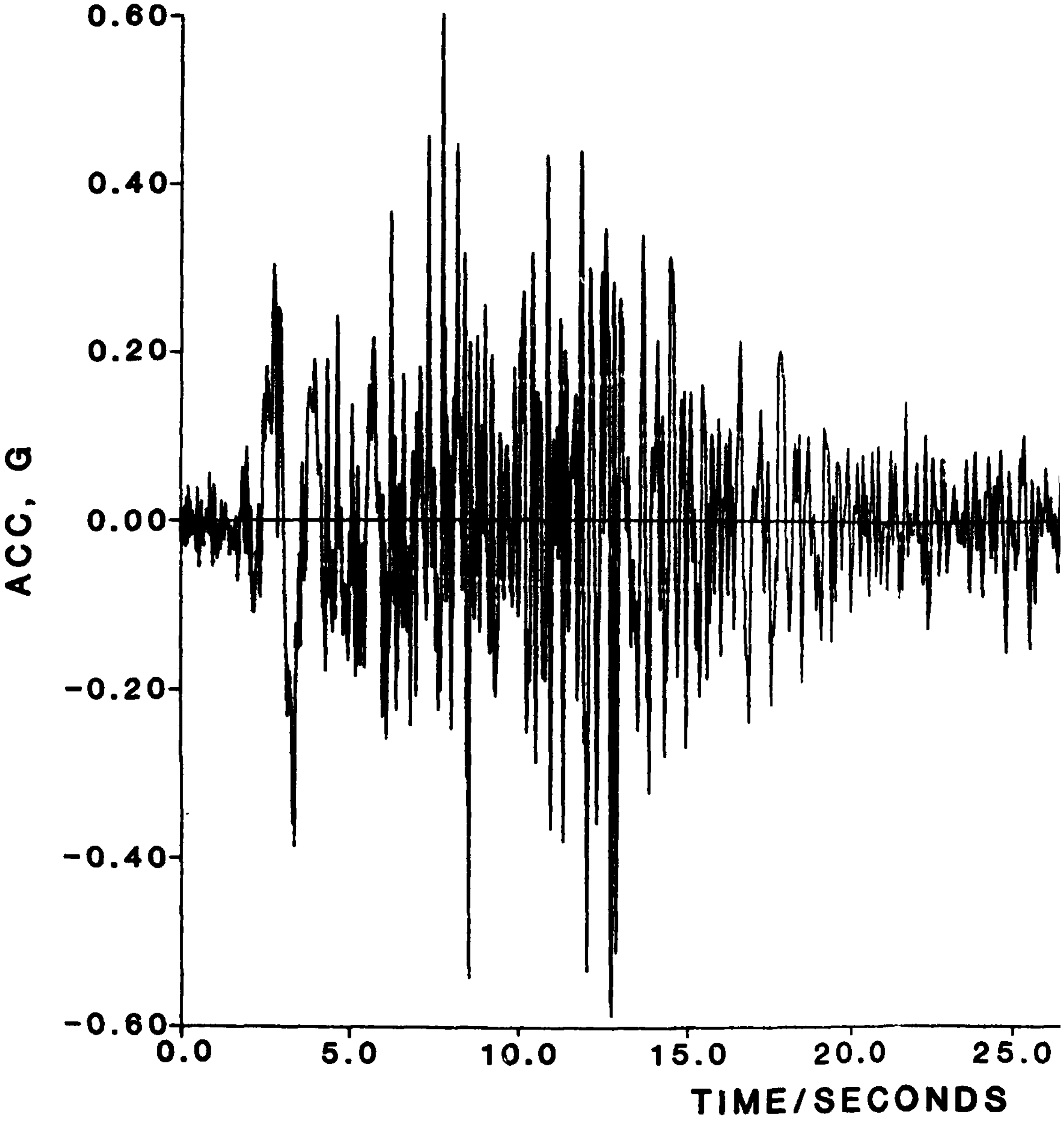
ACCELEROGRAPH OF SEED-IDRISS
8+ MAGNITUDE EARTHQUAKE

PLATE B-105

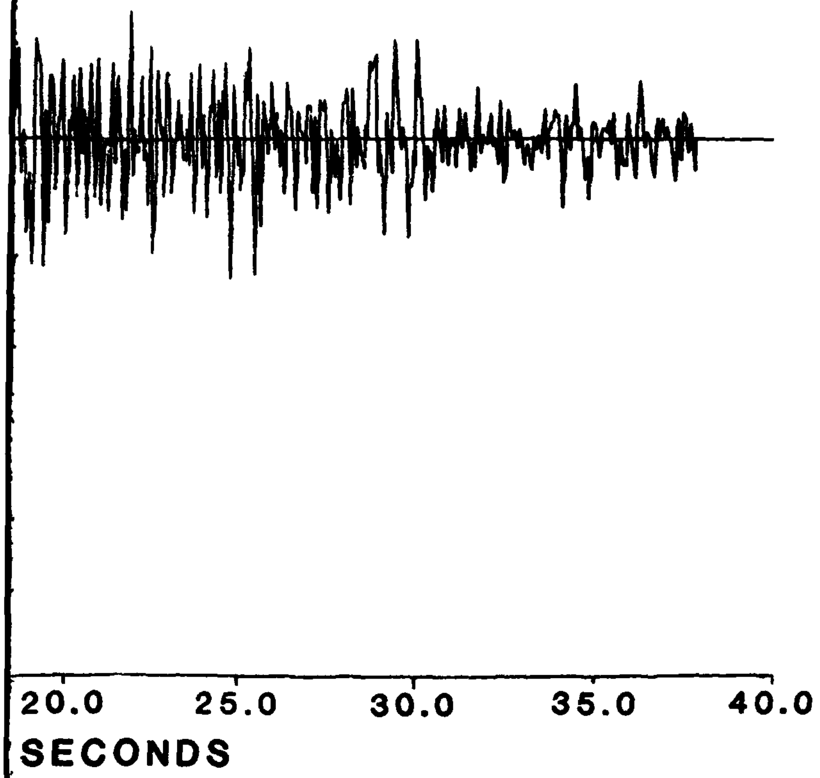
1

2

U. S. ARMY ENGINEER DISTRICT



EAST BAY MUD RECORD HAYWARD FAULT 7.5



FAULT 7.5 MAG SCALED TO 0.60G MAX

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

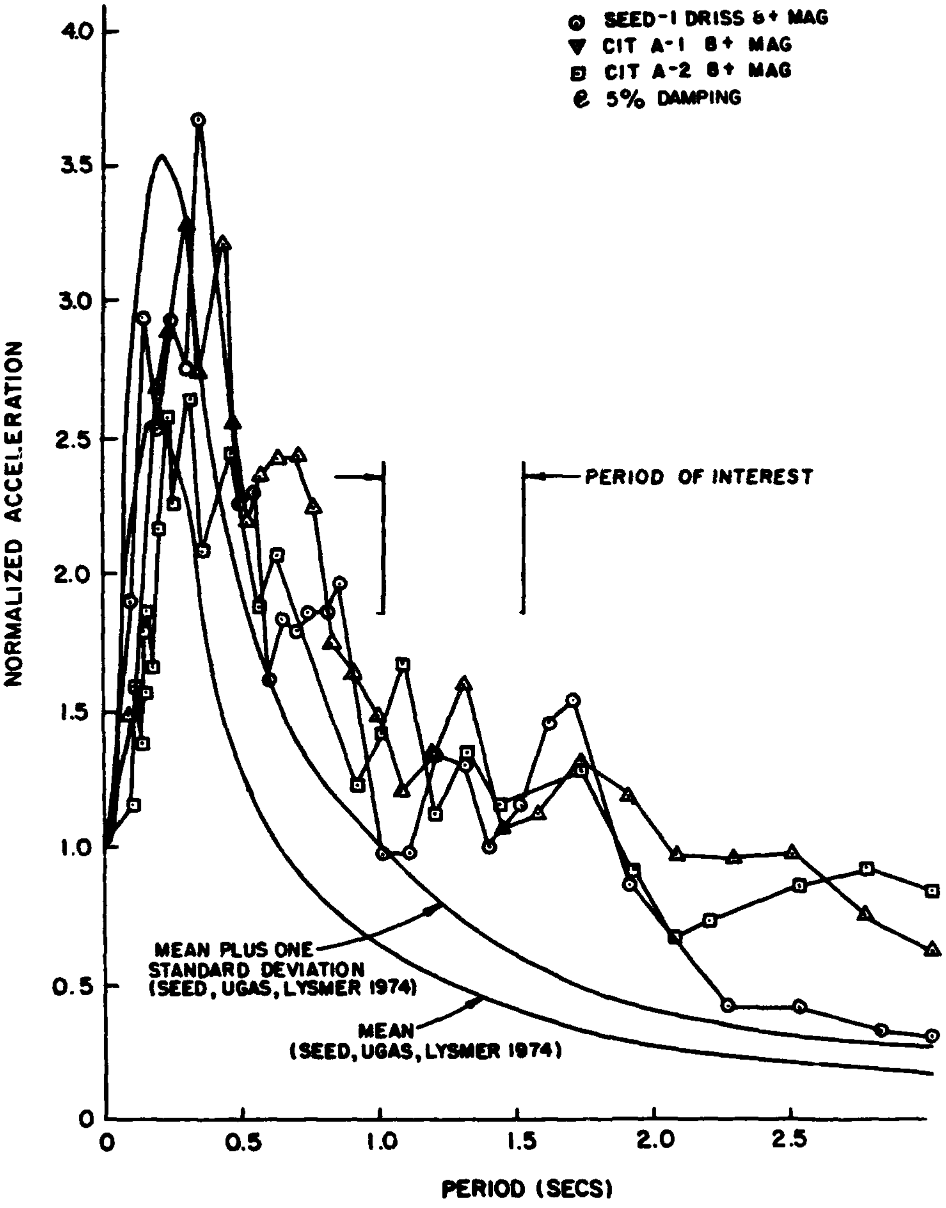
SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

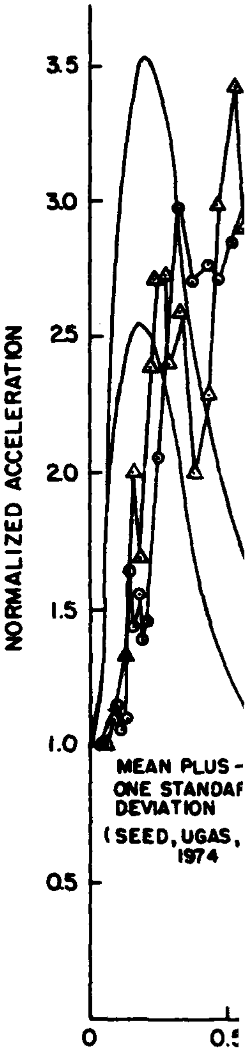
ACCELEROGRAPH OF SEED
ARTIFICIAL 7+ MAGNITUDE
EVENT

PLATE B-106

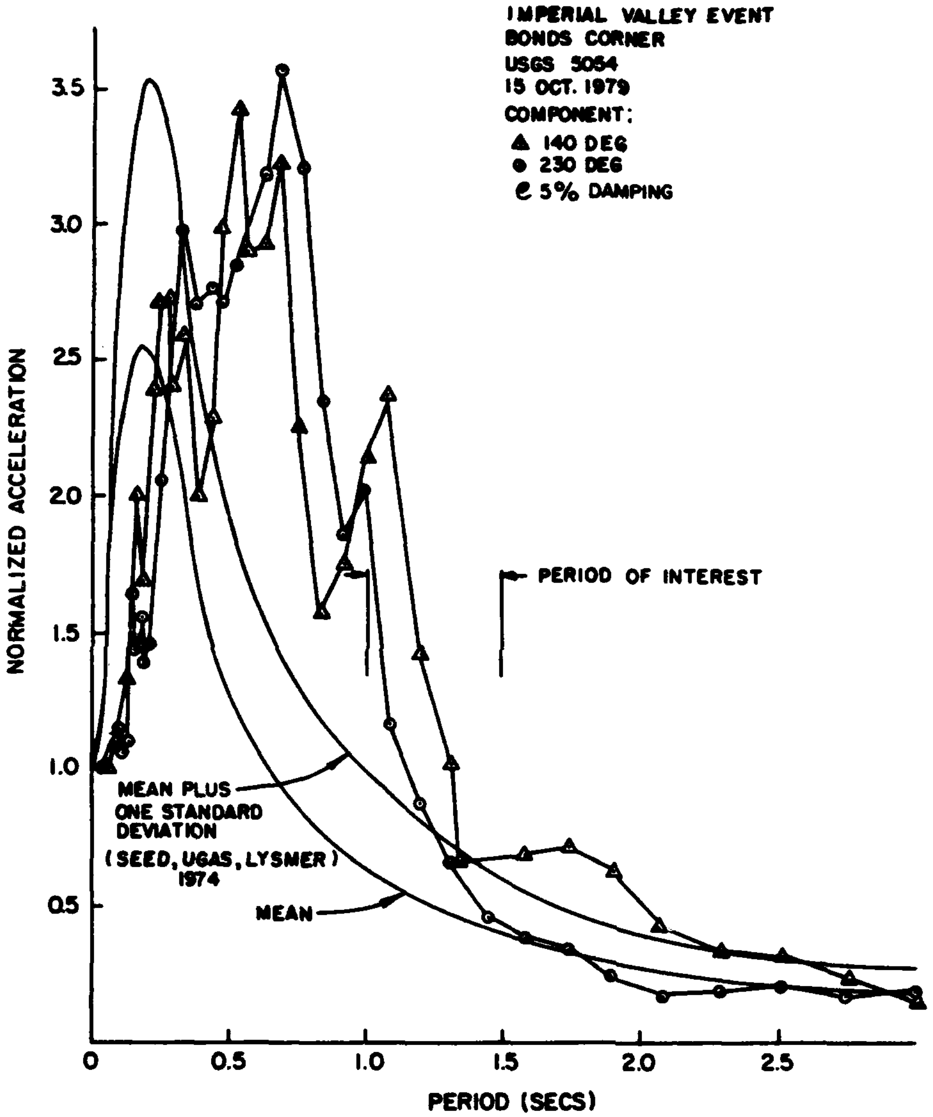
2



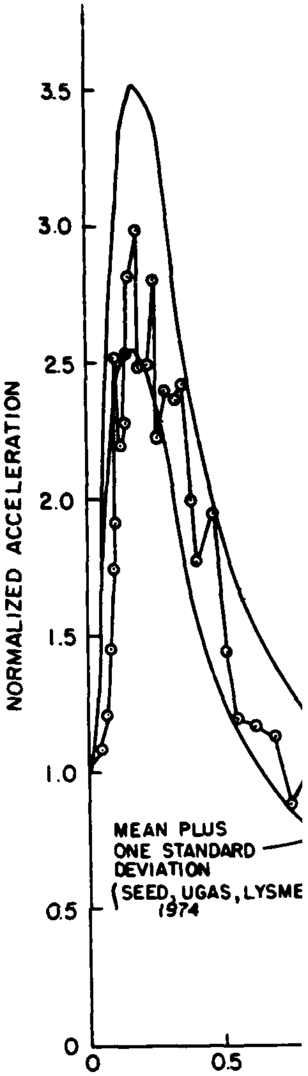
ACCELERATION RESPONSE SPECTRA OF THE SEED IDRISS ARTIFICIAL, CIT A-I AND CIT A-2 8+MAGNITUDE



ACCELER
CORNER AC



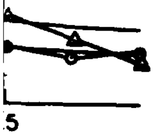
ACCELERATION RESPONSE SPECTRA OF THE BONDS CORNER ACCELEROGRAM FOR THE IMPERIAL VALLEY EVENT OF OCT. 15, 1979

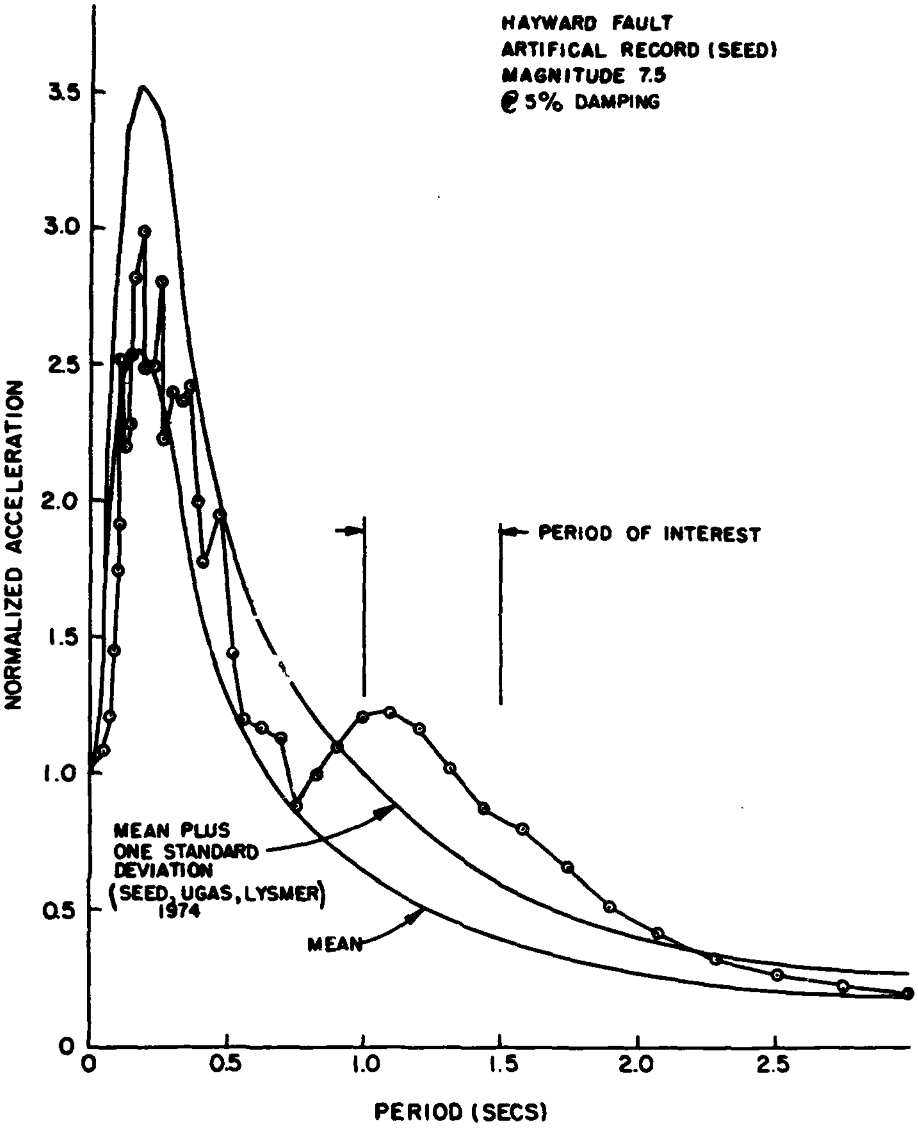


ACCELERA

ARTIFIC

1 2 1





ACCELERATION RESPONSE SPECTRA OF THE SEED
ARTIFICIAL 7.5 MAGNITUDE ACCELEROGRAM

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

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U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

NORMALIZED ACCELERATION RESPONSE SPECTRA

SUBMITTED BY:
DATE APPROVED:
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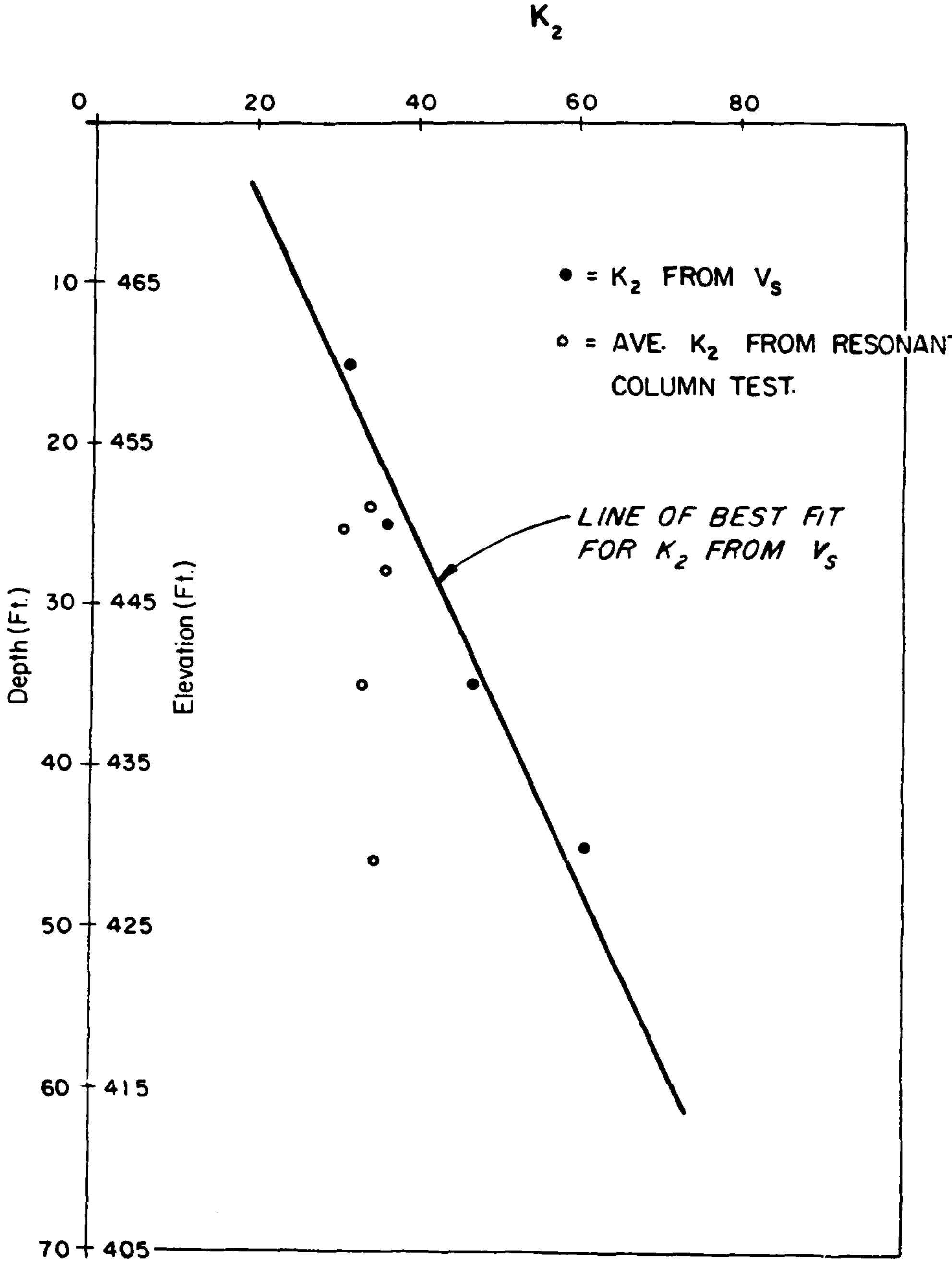
SHEET
DISTRICT FILE NO.

PLATE B-107

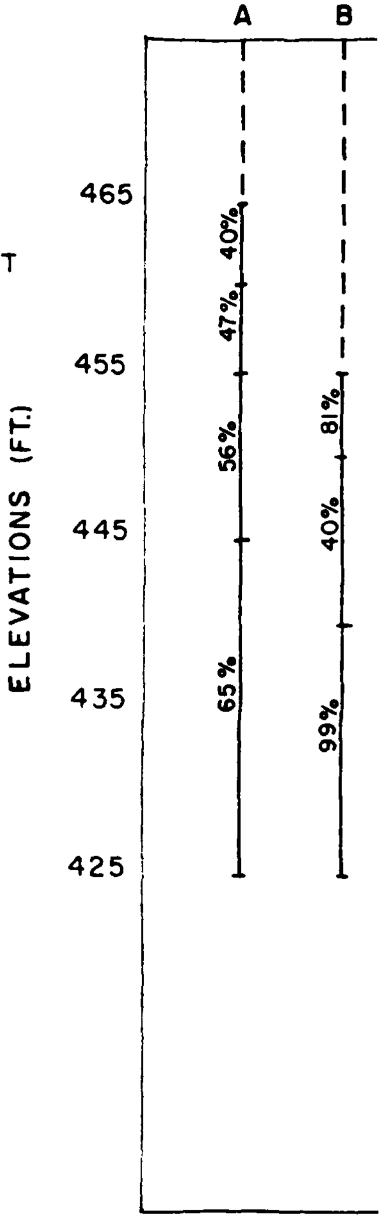
2

1

3

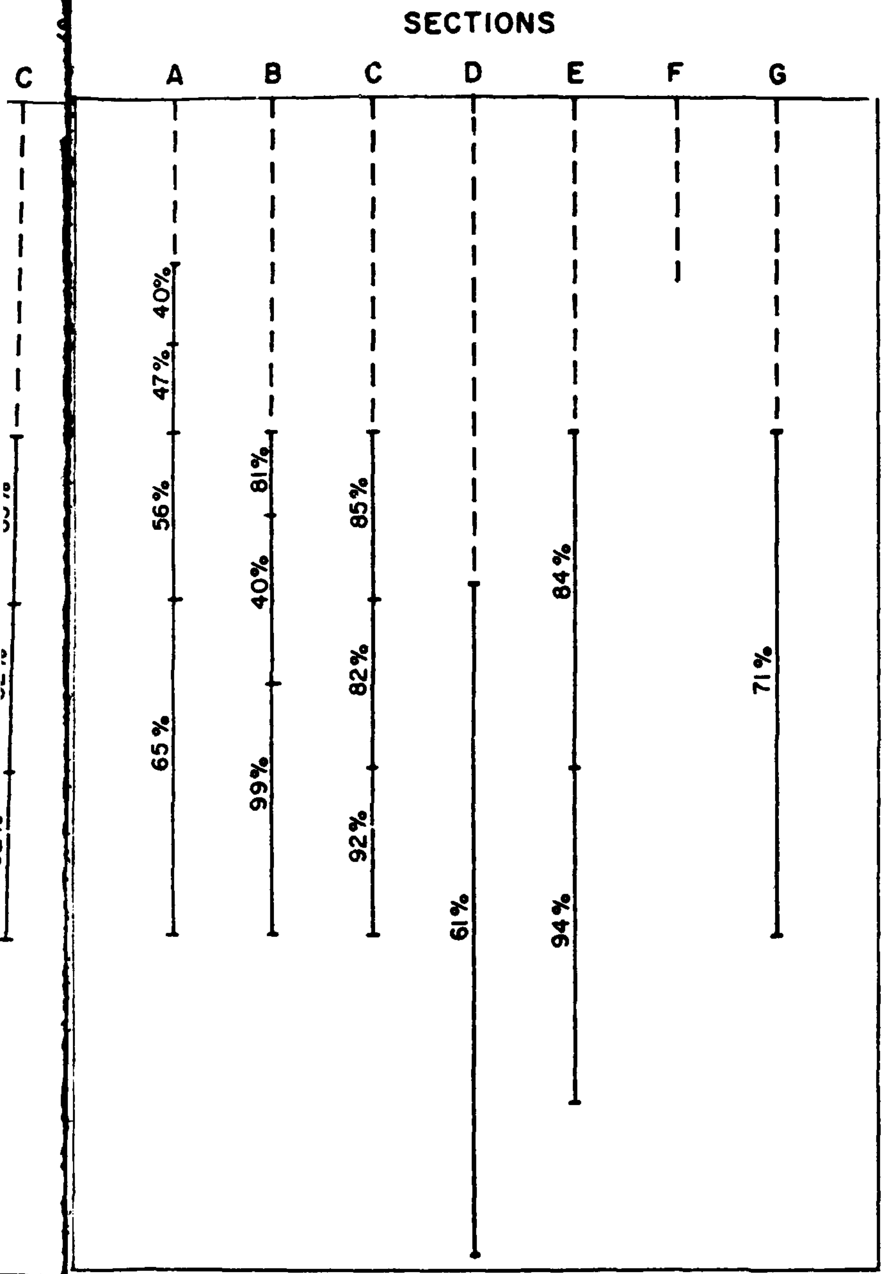


FOUNDATION FREE FIELD K_2 VALUES



AVERAGE

BA



AVERAGE APPARENT RELATIVE DENSITY
BASED ON SPT VALUES

LEGEND

1. See Plate B-14 for location of Sections.
2. Apparent D_r determined from studies conducted by Marcuson & Bieganousky.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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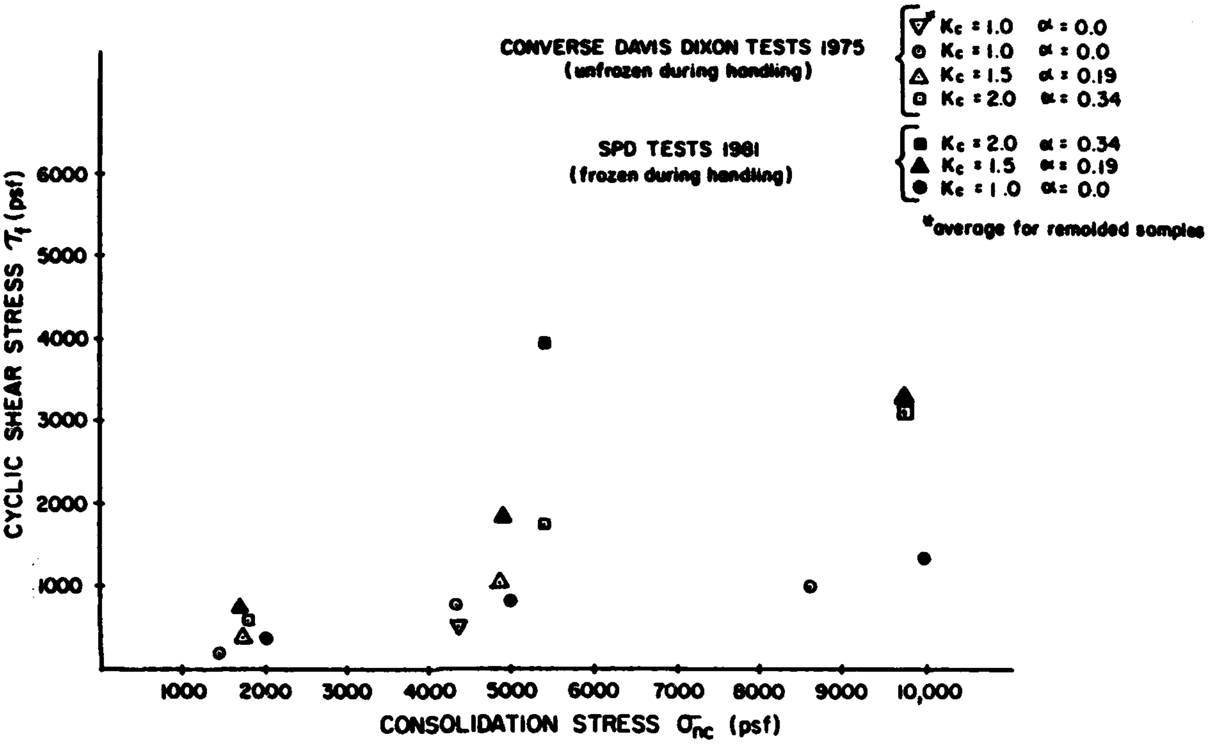
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM
PRADO DAM
DAM FOUNDATION FREE FIELD K_2 VALUES AND RELATIVE DENSITIES

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

PLATE B-108

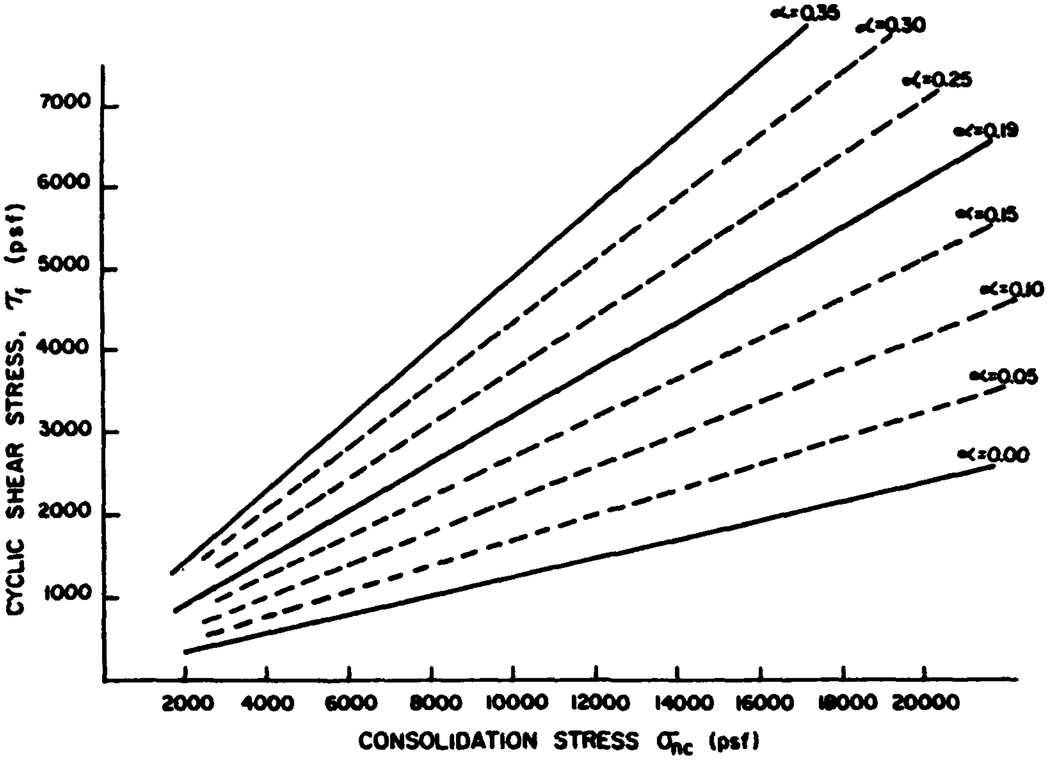
2



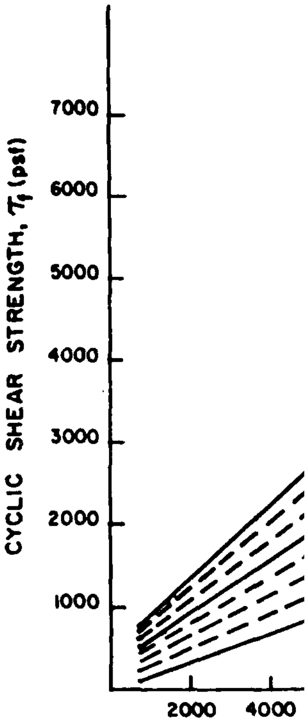
FOUNDATION MATERIAL COMPARISON OF CYCLIC SHEAR STRESS REQUIRED TO CAUSE 5% STRAIN IN 20 CYCLES FOR FROZEN AND UNFROZEN SAMPLES.

0
0
19
34

34
19
0
ded samples

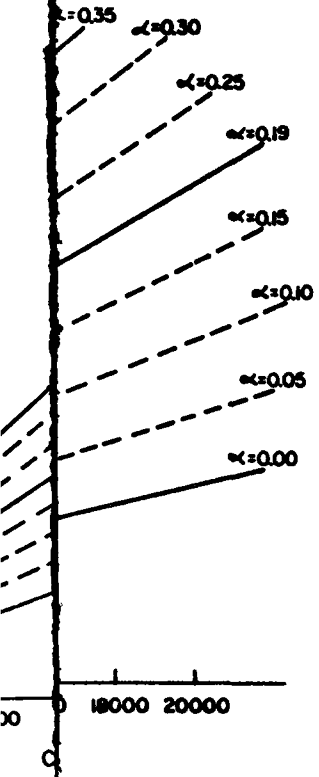


FOUNDATION MATERIAL CYCLIC MATERIAL STRESS REQUIRED TO CAUSE
5% STRAIN IN 20 CYCLES

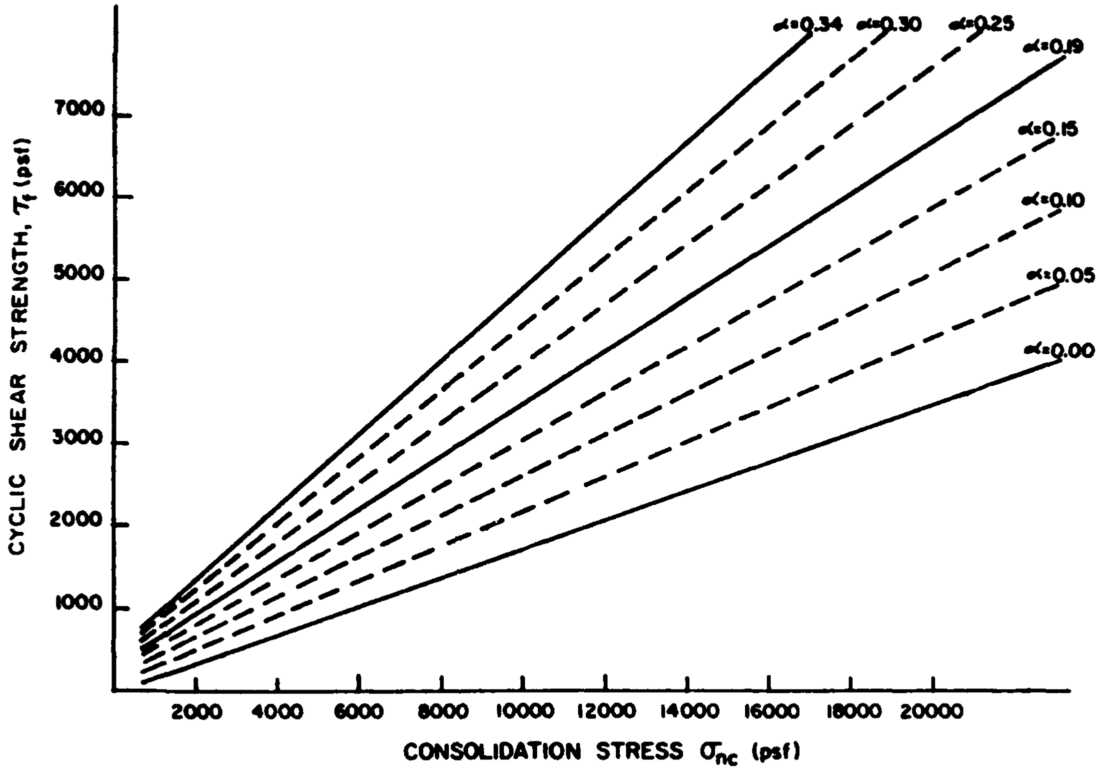


1

2



IRED TO CAUSE



SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

DAM FOUNDATION MATERIALS
CYCLIC SHEAR STRENGTH

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

PLATE B-109

2

1

3

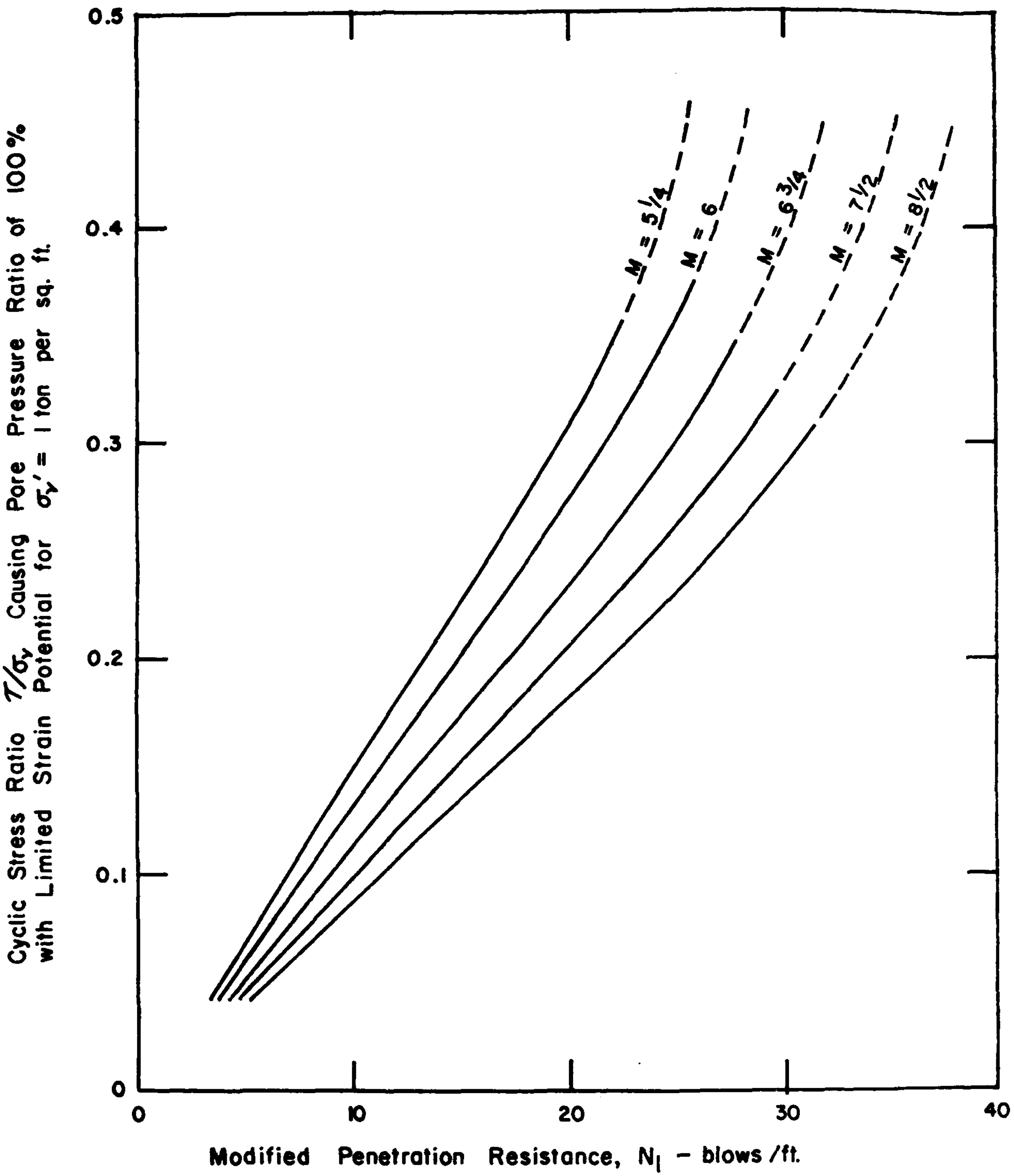
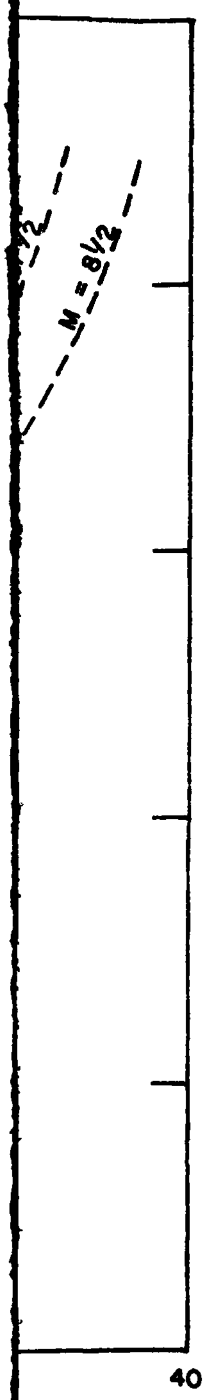


CHART FOR EVALUATION OF LIQUEFACTION POTENTIAL FOR DIFFERENT MAGNITUDE EARTHQUAKES FOR LEVEL GROUND CONDITIONS.



ENTIAL
LEVEL

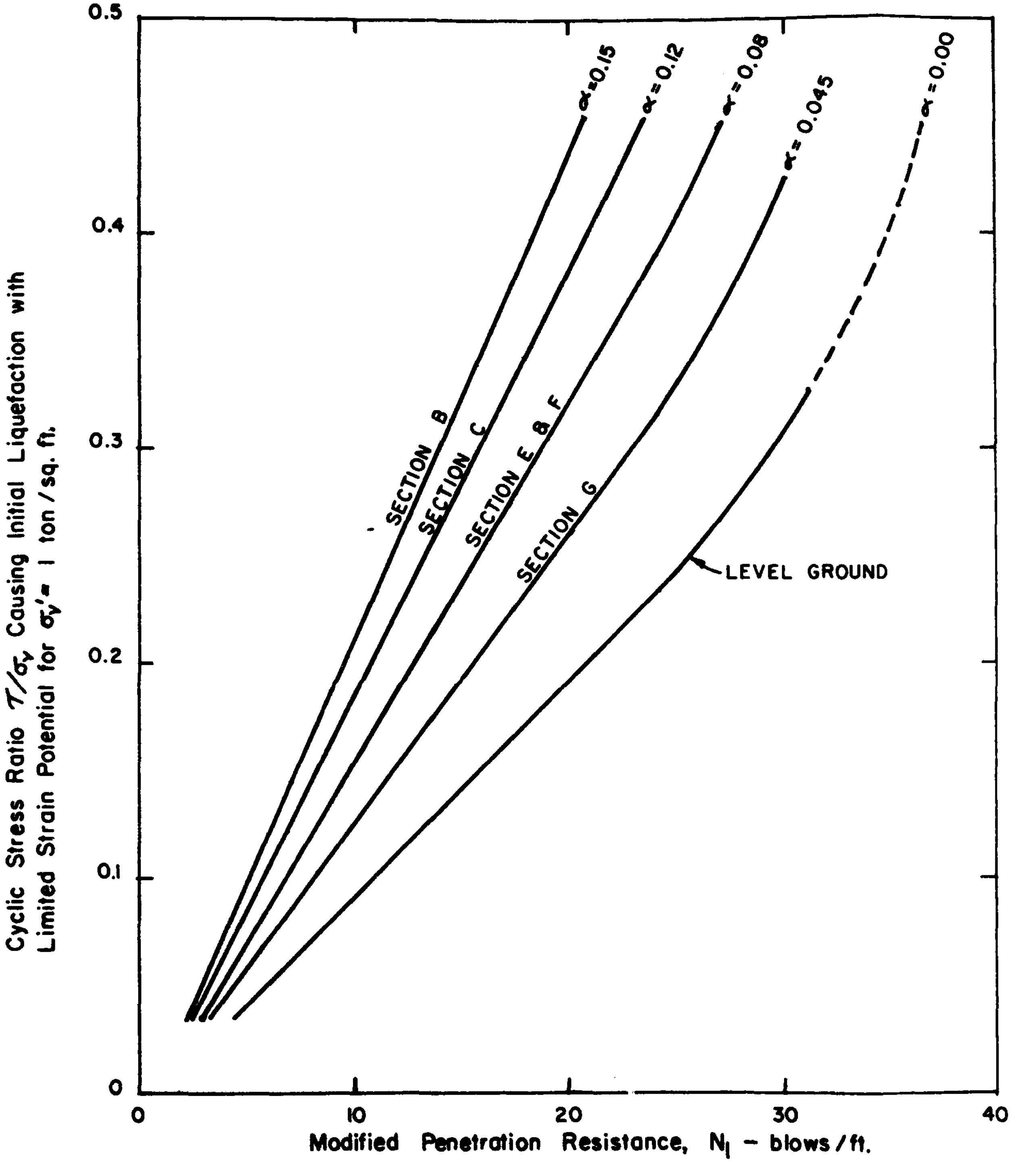
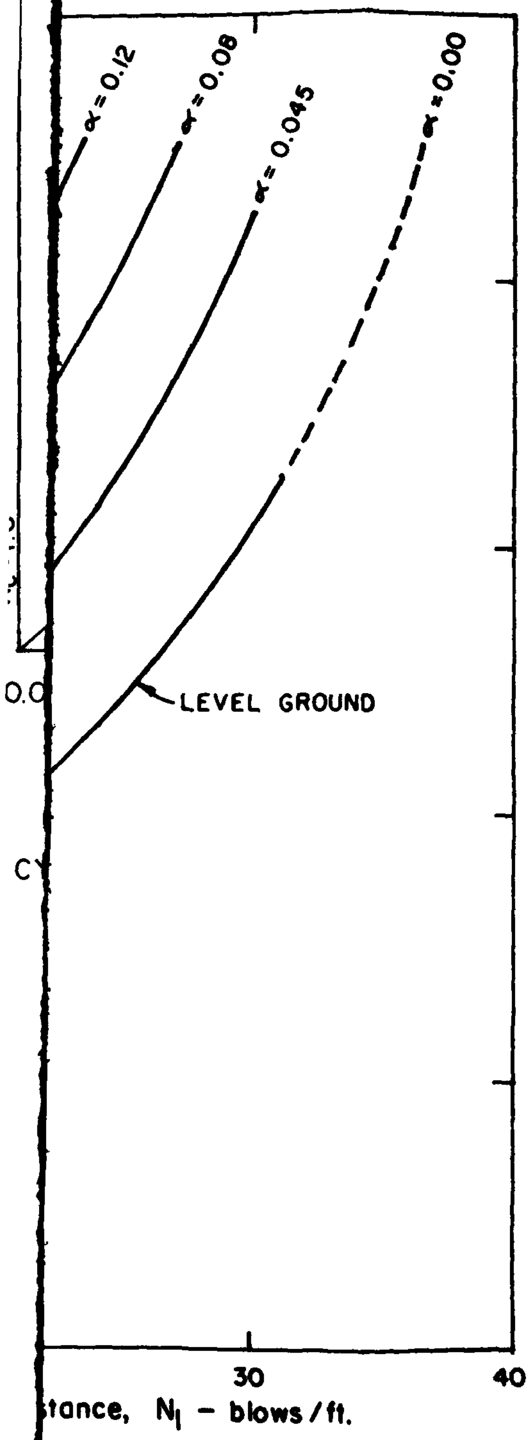
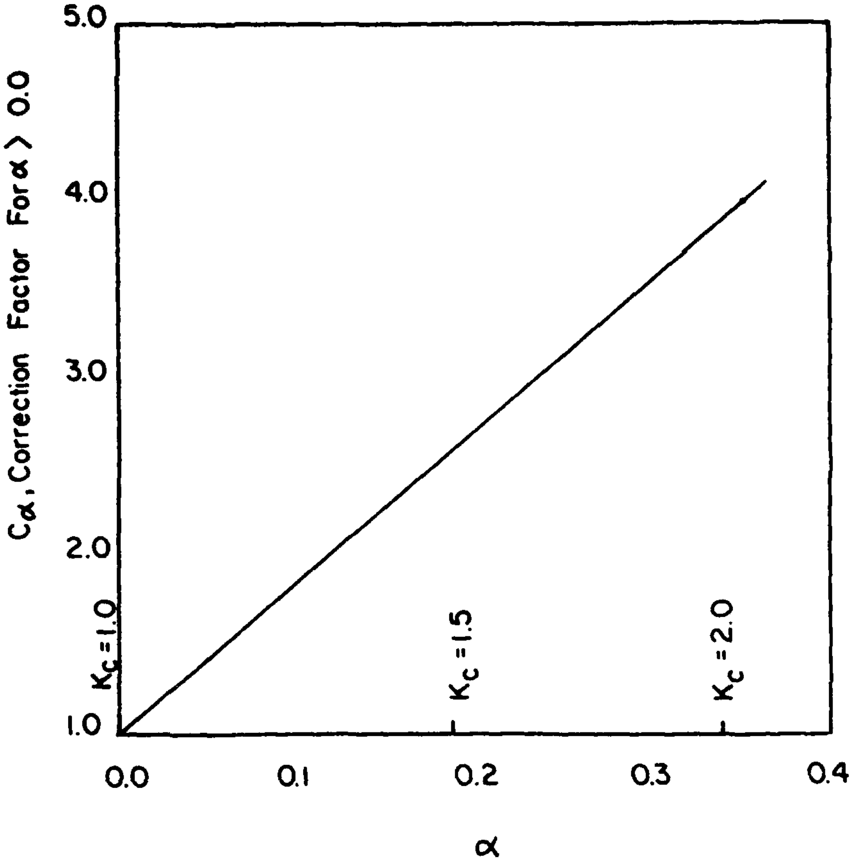


CHART FOR ELEVATION OF LIQUEFACTION POTENTIAL
OF SANDS FOR LEVEL AND SLOPING GROUND CONDITIONS
AND 8 + MAGNITUDE EARTHQUAKE.

Cα, Correction Factor For α > 0.0



F LIQUEFACTION POTENTIAL
SLOPING GROUND CONDITIONS
HQUAKE.



CYCLIC SHEAR STRESS CORRECTION FACTOR
FOR SLOPING GROUND CONDITIONS ($\alpha > 0.0$)

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

EVALUATION OF LIQUEFACTION POTENTIAL

DATE APPROVED

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

SHEET

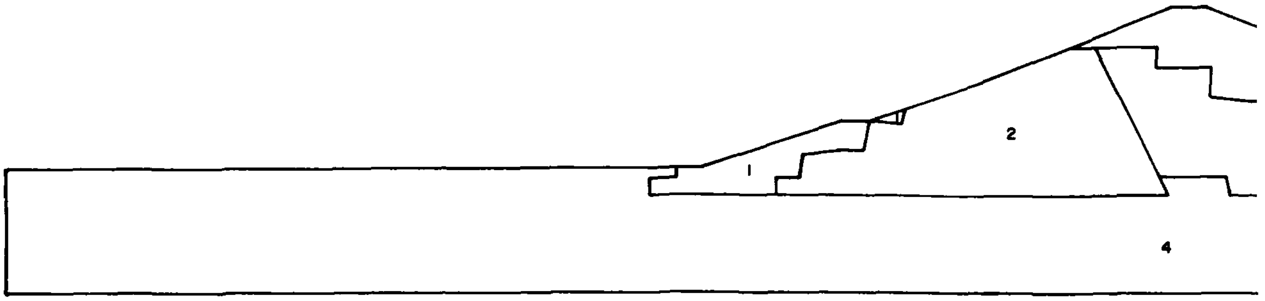
PLATE B-110

2

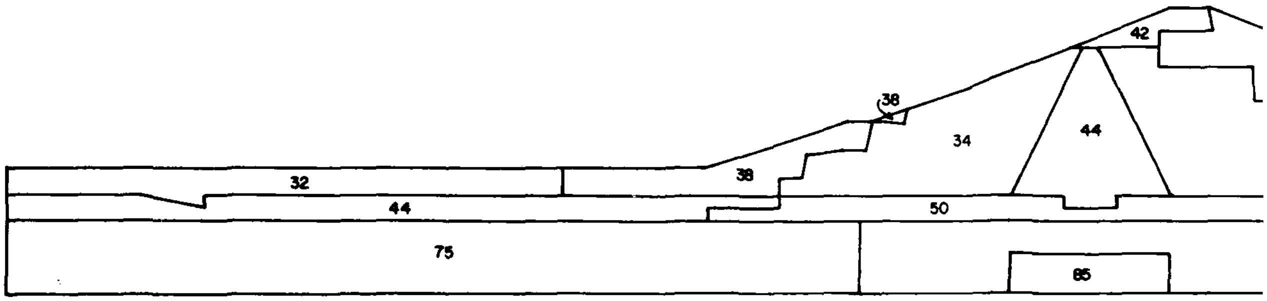
1

3

VALUE ENGINEER



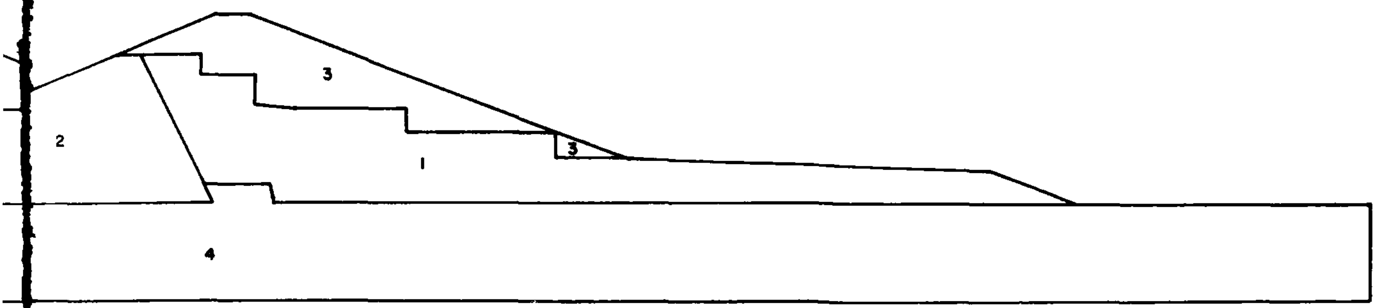
FEM DYNAMIC MATERIAL PF



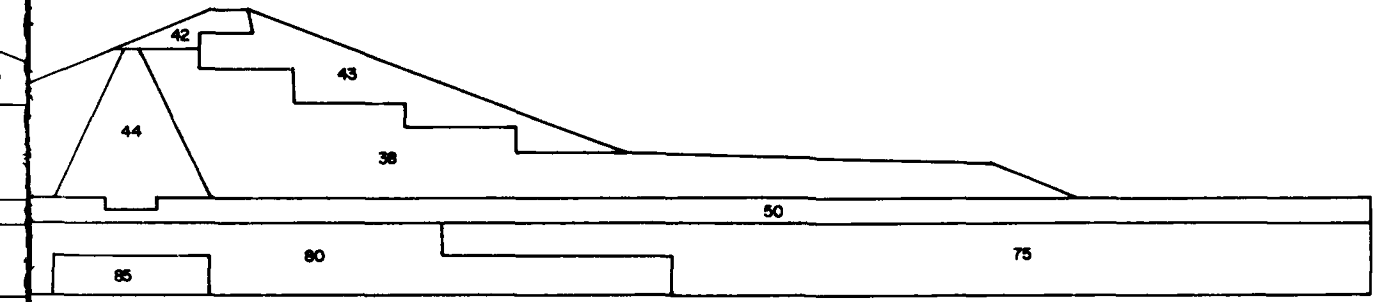
DYNAMIC FEM K_2 PARAM

SAFETY P

1



RTM DYNAMIC MATERIAL PROPERTIES



RS DYNAMIC FEM K_2 PARAMETERS

NOTE:

1. SEE TABLE 27 FOR DYNAMIC MATERIAL PROPERTY VALUES.

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

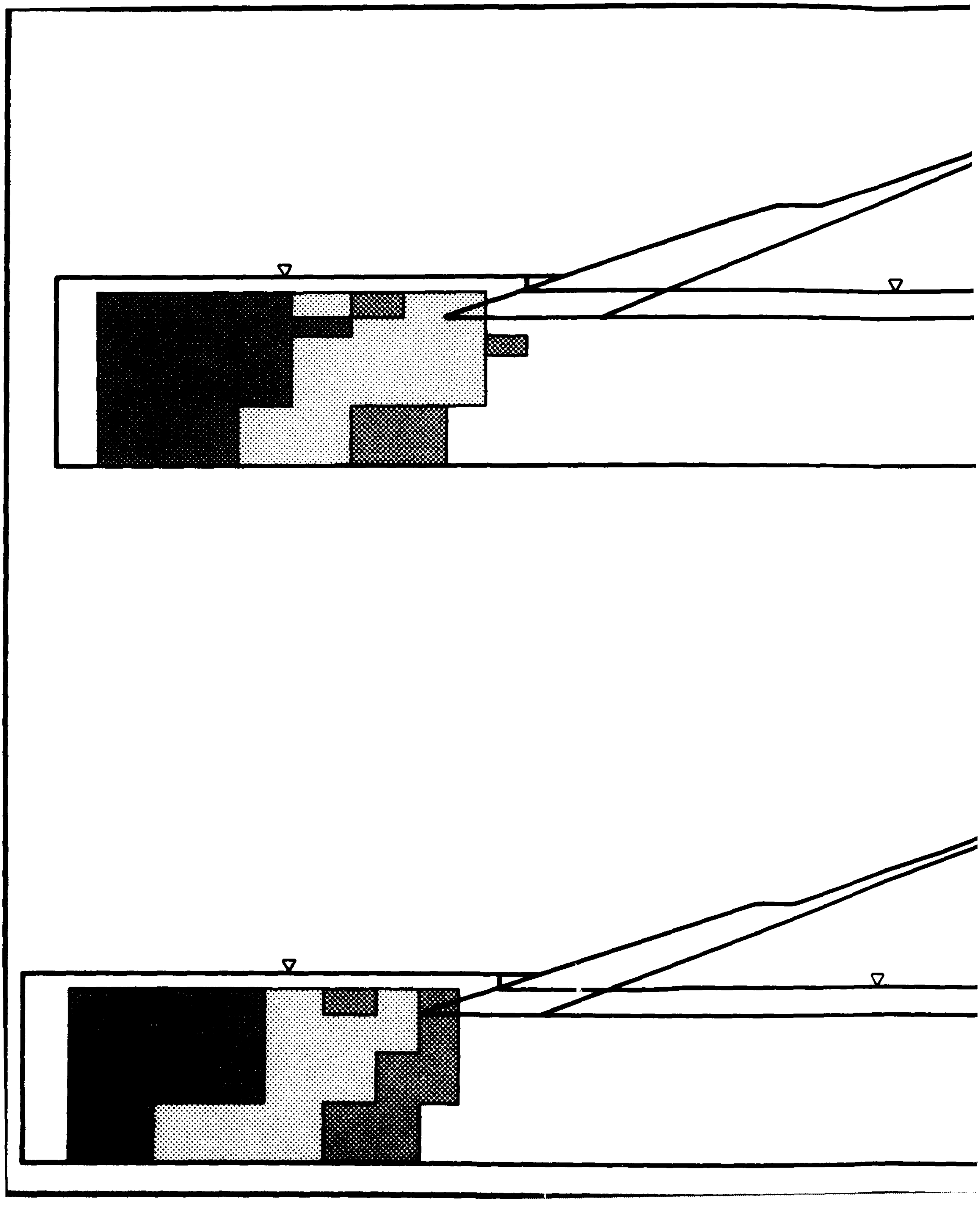
DYNAMIC FINITE ELEMENT MESH
MATERIAL PROPERTIES

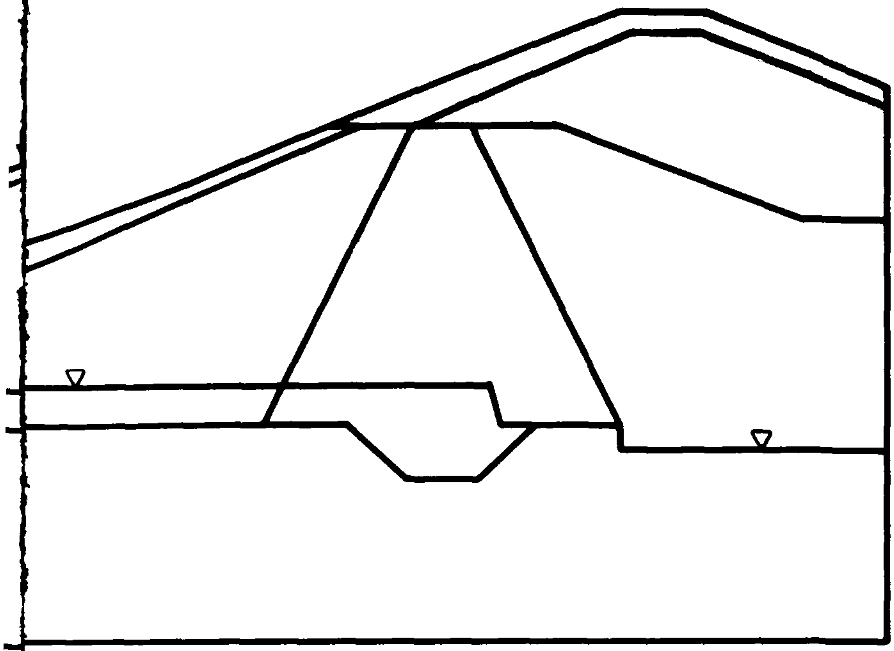
SUBMITTED BY:
DATE APPROVED
SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO.
SHEET

PLATE 6-111

1

2





Seed-Idriss
Artificial Record

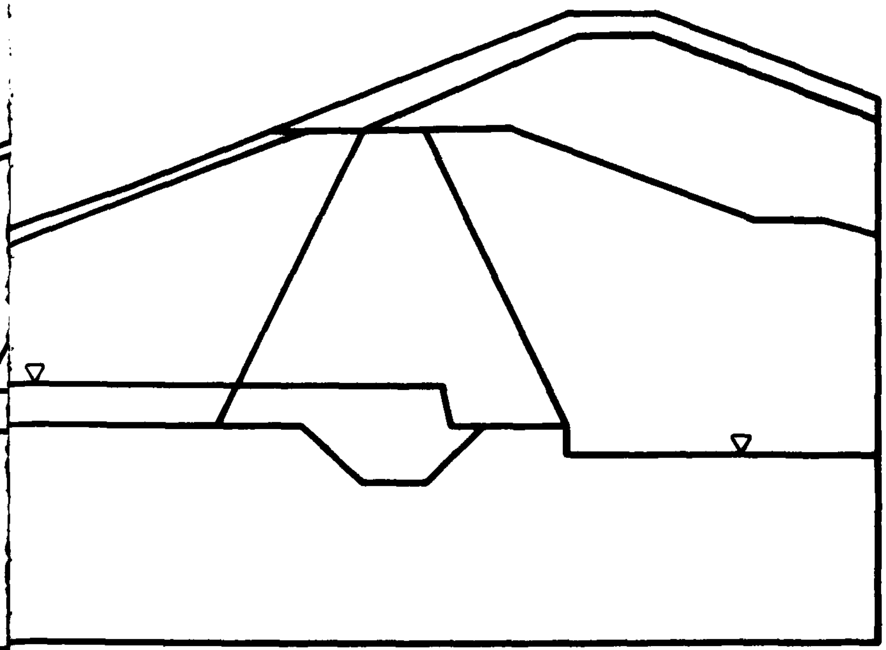
8 + M

0.30g 45 sec.

Empty Pool Condition

▓	0.4-0.6	F.S.
░	0.6-0.8	
▒	0.8-1.0	
☐	1.0 +	

$$\text{F.S.} = \frac{\text{Lab. Dynamic Shear Stress } @ \epsilon_{da} = 10\% \text{ for 10 or 20 Cycles}}{\text{Dynamic Shear Stress for 10 or 20 Equiv. Cycles}}$$



Seed
Artificial Record

7+M

0.60g 30sec

Empty Pool Condition

▓	0.4-0.6	F.S.
░	0.6-0.8	
▒	0.8-1.0	
☐	1.0 +	

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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CHECKED BY:

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

DYNAMIC RESPONSE TO LOCAL
AND REGIONAL EARTHQUAKES
FOR THE
POOL EMPTY CONDITION

SUBMITTED BY:

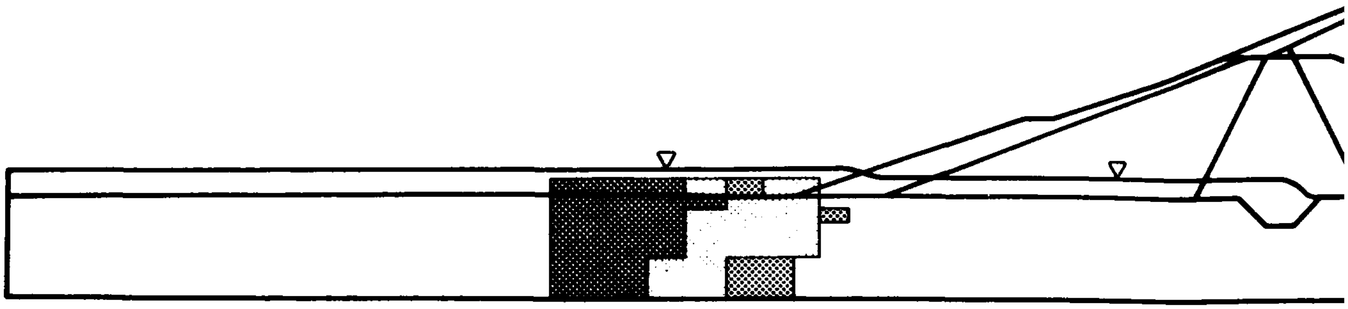
DATE APPROVED:

SPEC. NO. DACW09-___ B-___

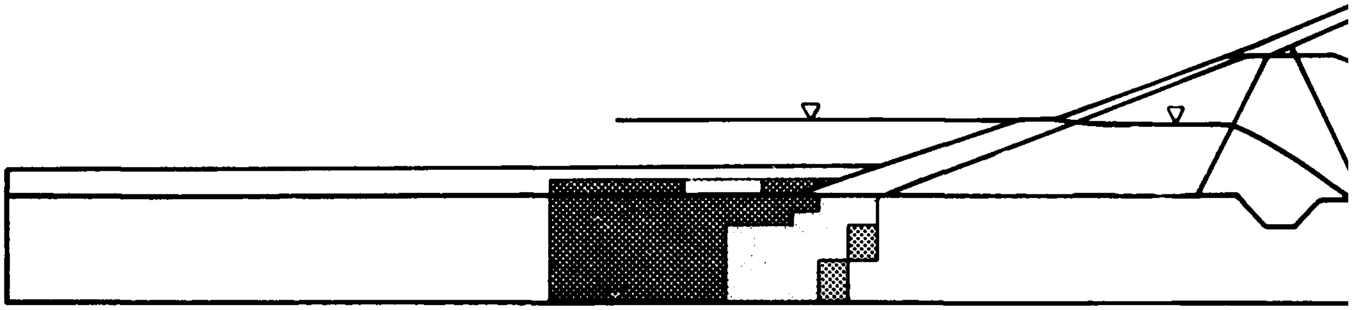
SHEET OF

DISTRICT FILE NO.

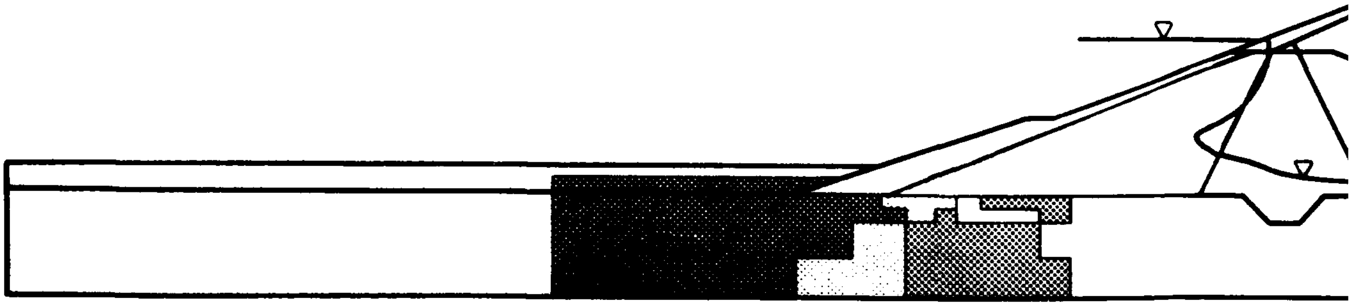
PLATE B-112



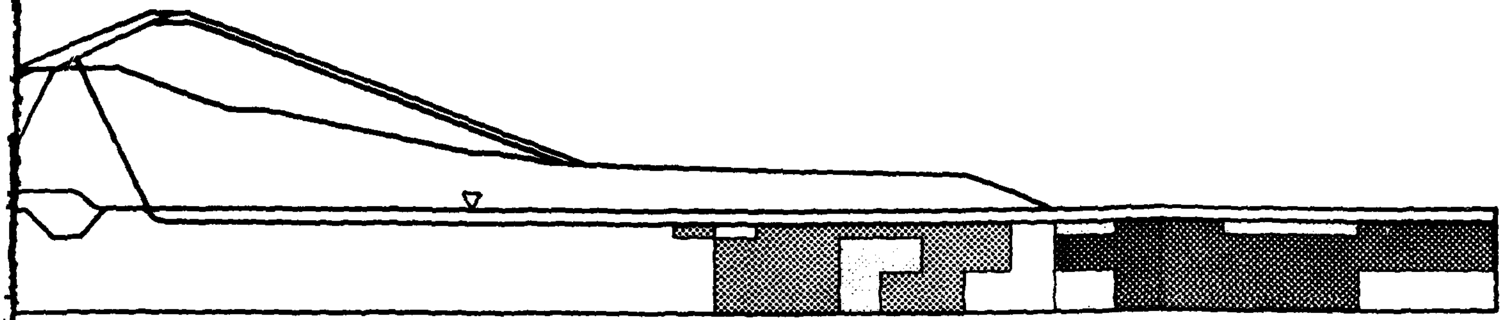
POO



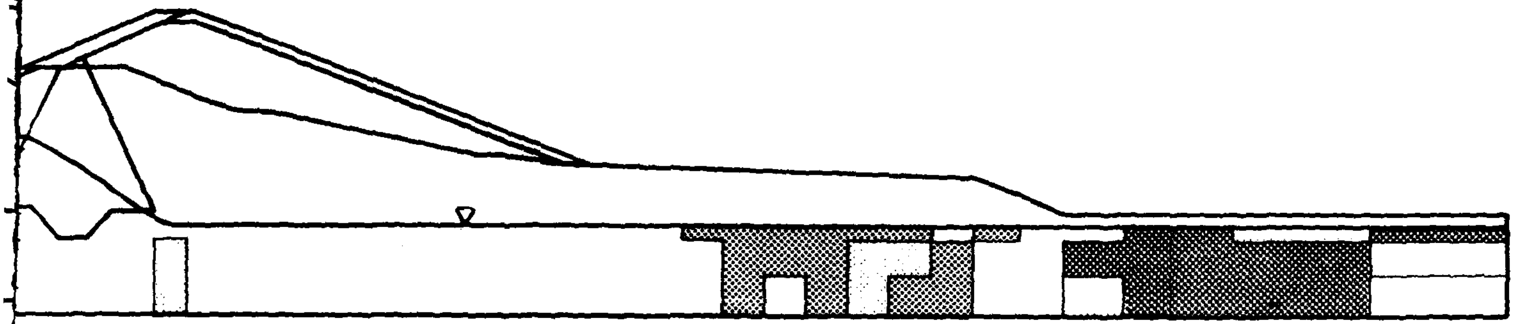
P



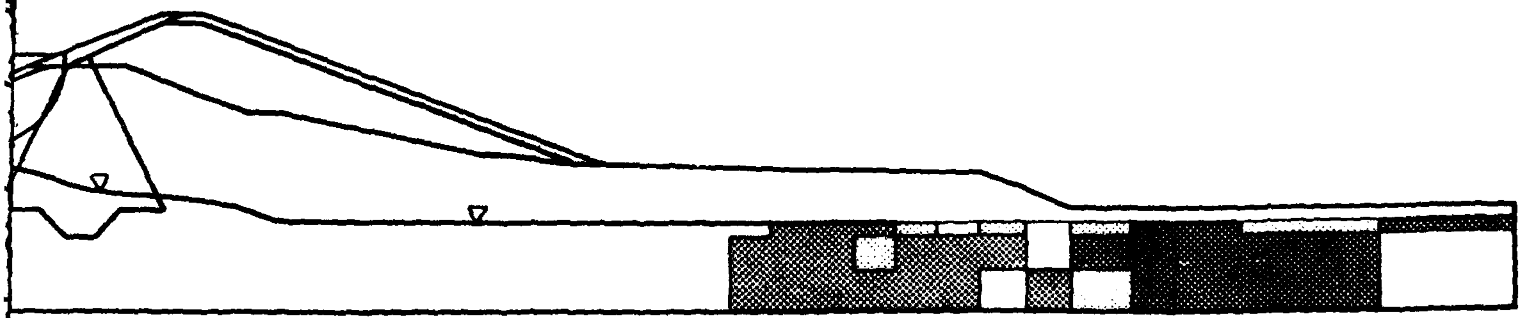
FLOOD PO



POOL EMPTY

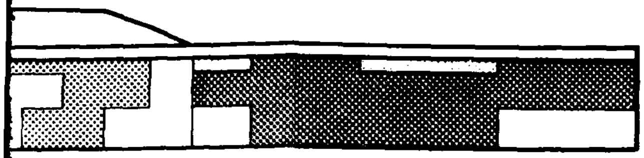


POOL @ EL. 500



LOOD POOL @ EL. 562.9

1 2 1



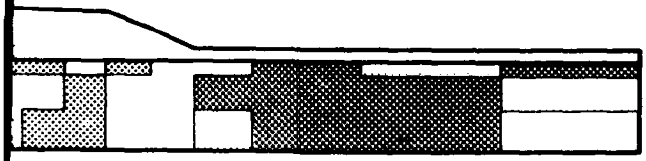
FS

■ 0.4-0.6

▭ 0.6-0.8

▨ 0.8-1.0

☐ 1.0 +



SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

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DRAWN BY:

CHECKED BY:

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM
PRADO DAM
DYNAMIC RESPONSE TO AN +8 MAG.
EVENT FOR POOL EMPTY,
POOL EL. 500,
FLOOD POOL EL. 562.9

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW 09-____ B-____

DISTRICT FILE NO.

SHEET

PLATE B-113

2

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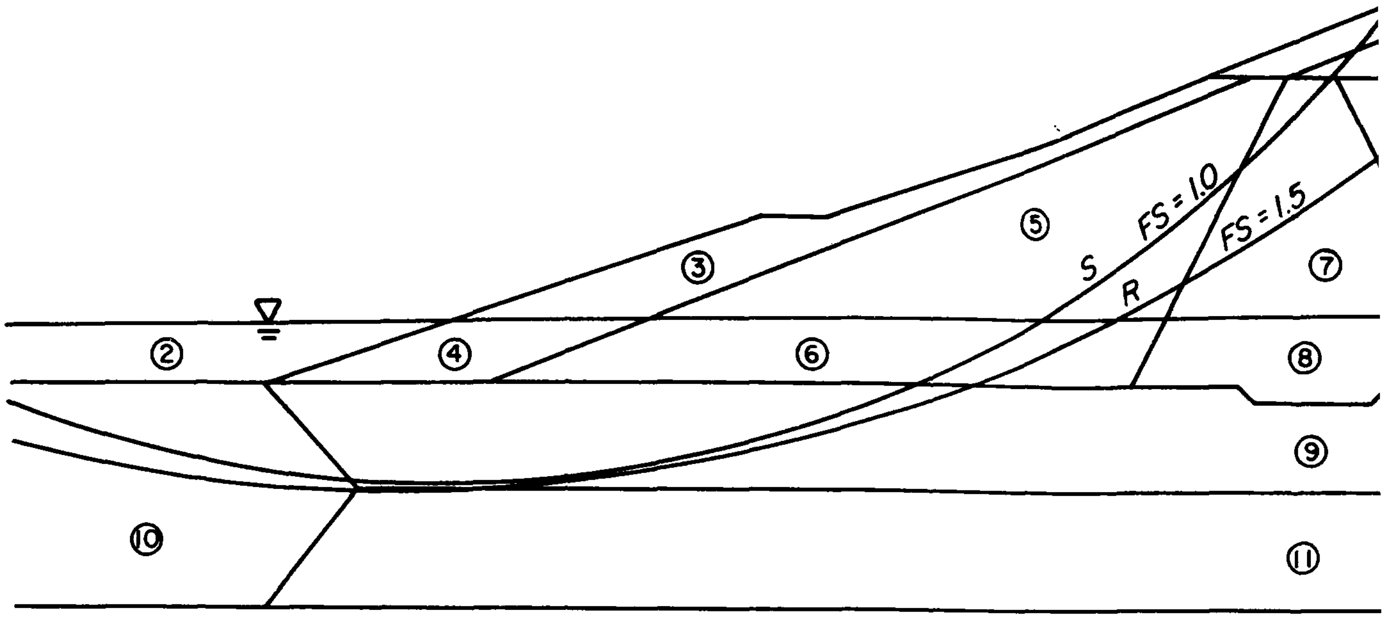
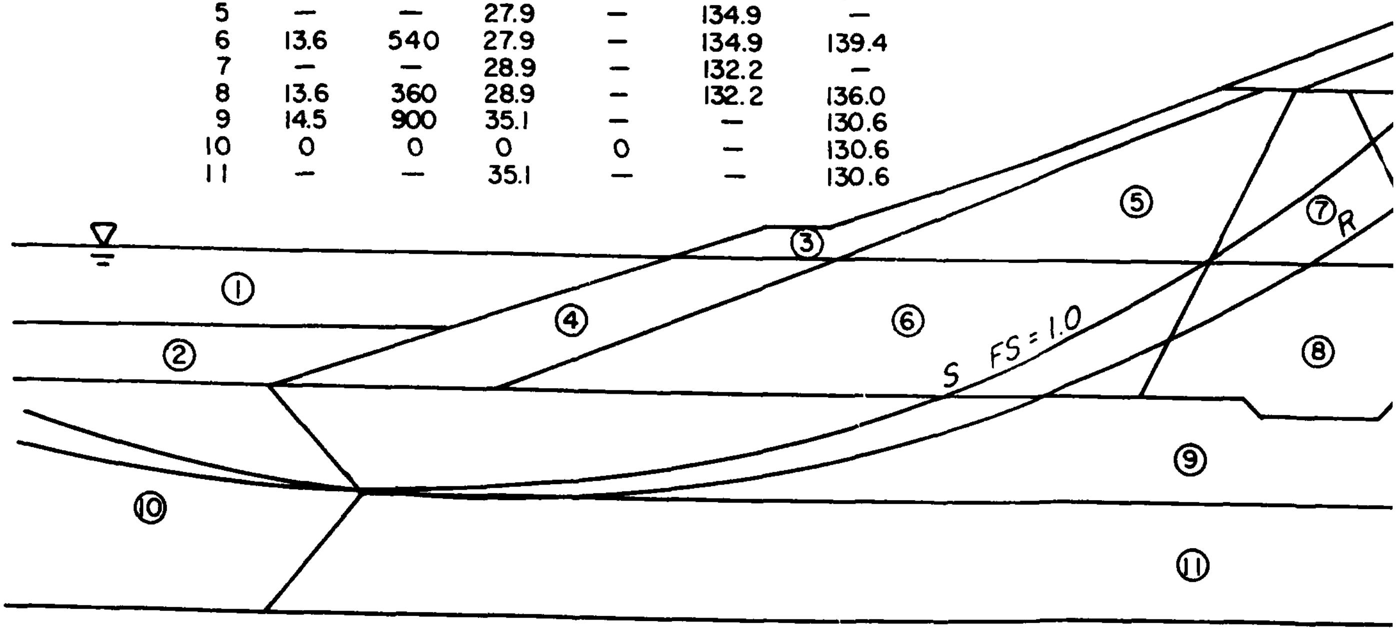


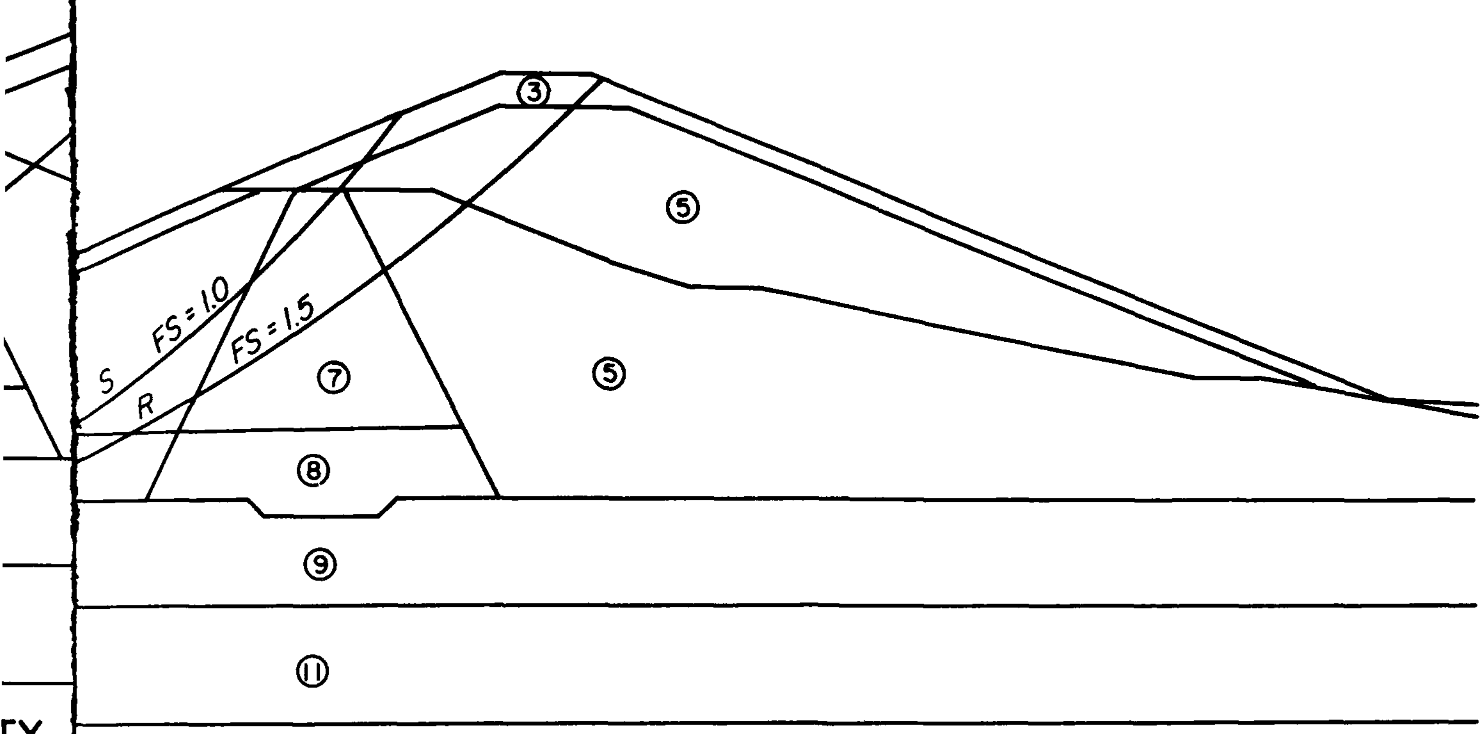
POOL EM

SHEAR STRENGTHS

	R		S		γm	γsat
	φ	C(psf)	φ	C(psf)	(pcf)	(pcf)
1	0	0	0	0	—	62.4
2	—	200	—	200	—	106.0
3	—	—	34.1	—	135.3	—
4	29.4	1440	34.1	—	135.3	139.5
5	—	—	27.9	—	134.9	—
6	13.6	540	27.9	—	134.9	139.4
7	—	—	28.9	—	132.2	—
8	13.6	360	28.9	—	132.2	136.0
9	14.5	900	35.1	—	—	130.6
10	0	0	0	0	—	130.6
11	—	—	35.1	—	—	130.6



POOL @ EL. 500

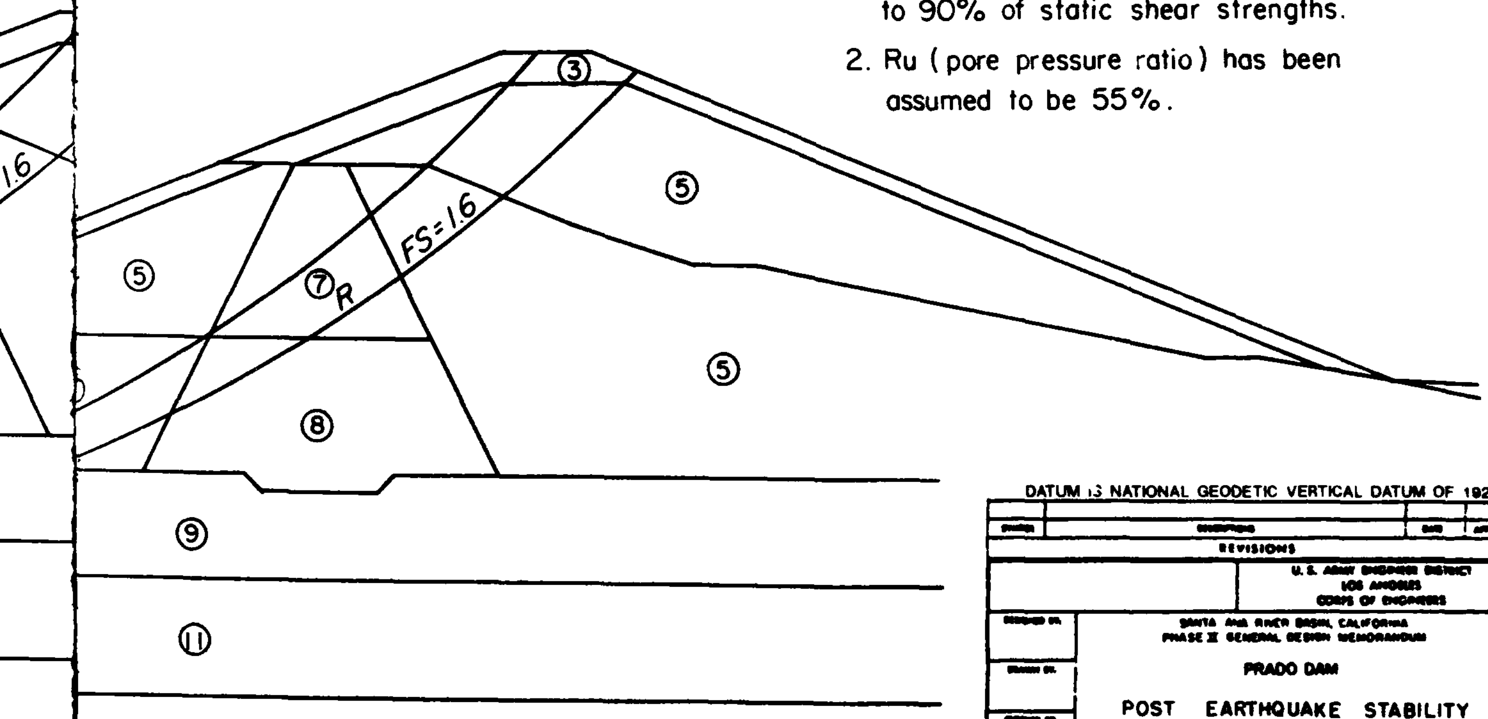


TY

POOL EMPTY

NOTES:

1. R and S shear strengths are reduced to 90% of static shear strengths.
2. Ru (pore pressure ratio) has been assumed to be 55%.



OL @ EL. 500

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

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U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

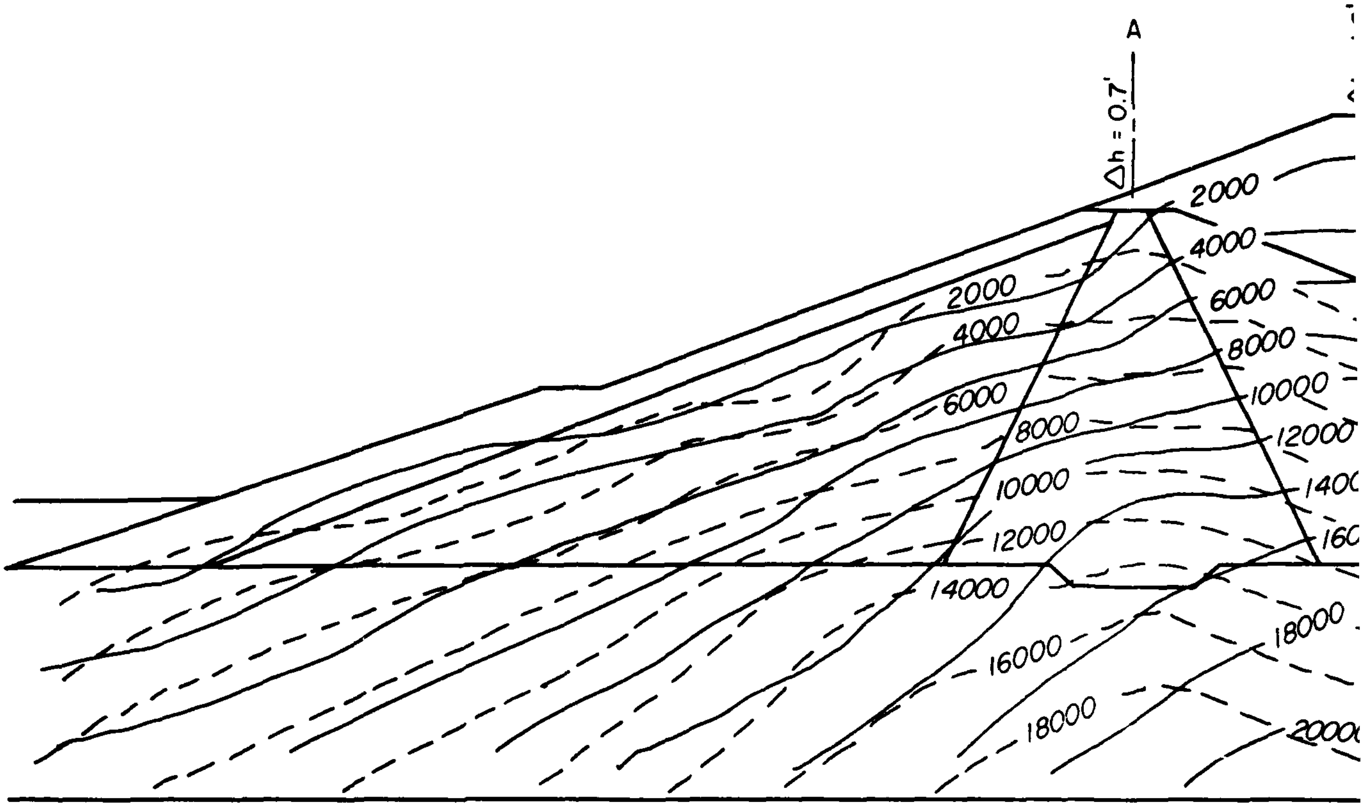
SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

POST EARTHQUAKE STABILITY ANALYSIS

PLATE B-114

2

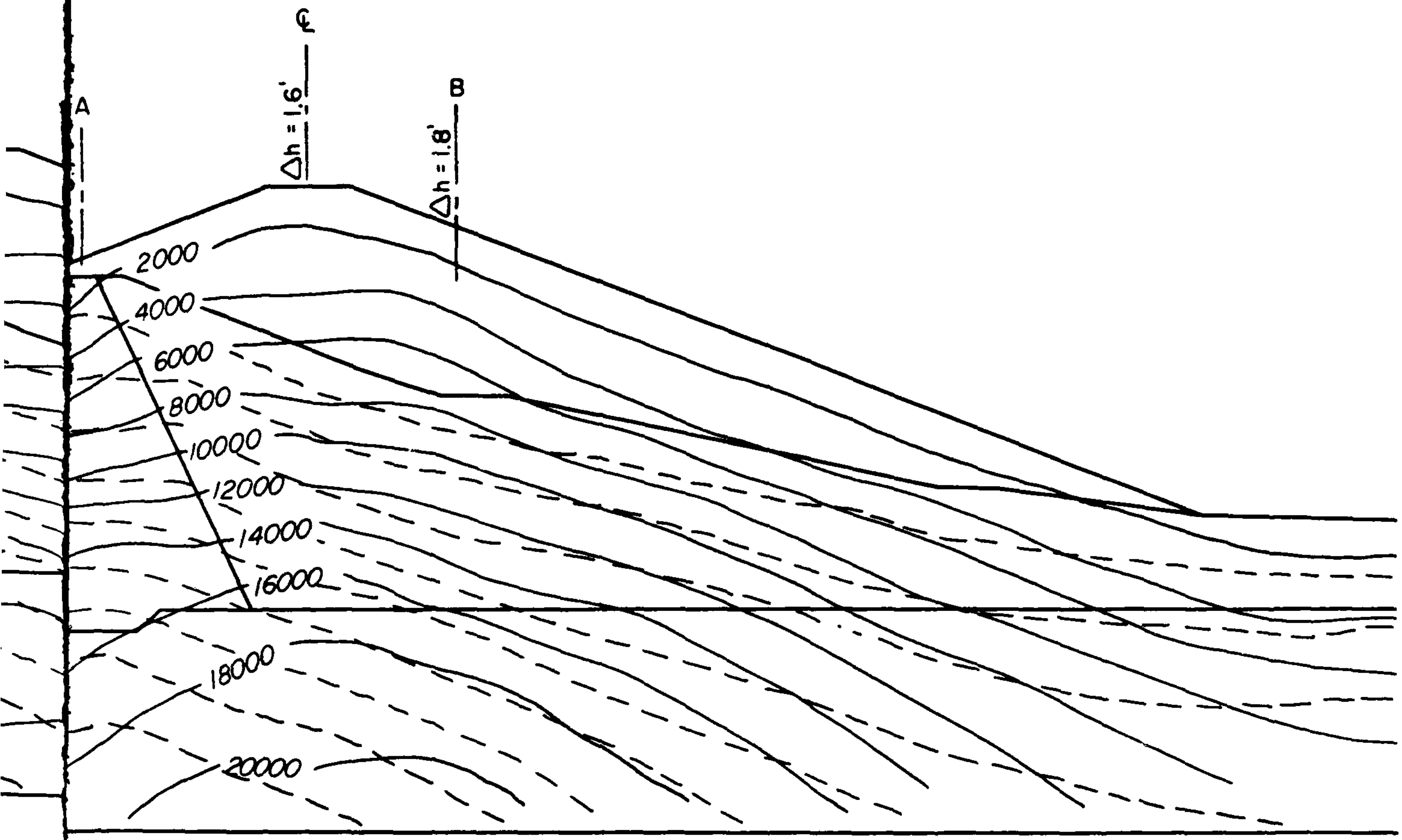


VERTICAL

SCALE: 1 IN

50 0 5

— — — EXISTING VERTICAL STRESSES
——— POST CONSTRUCTION VERTICAL STRESSES
Δh SETTLEMENT

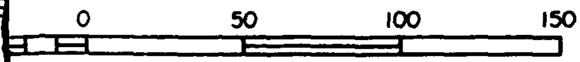


RES

0 FT.

VERTICAL STRESSES

SCALE: 1 IN. = 50 FT.



SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

EXISTING & POST CONSTRUCTION
VERTICAL STRESSES &
SETTLEMENTS

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

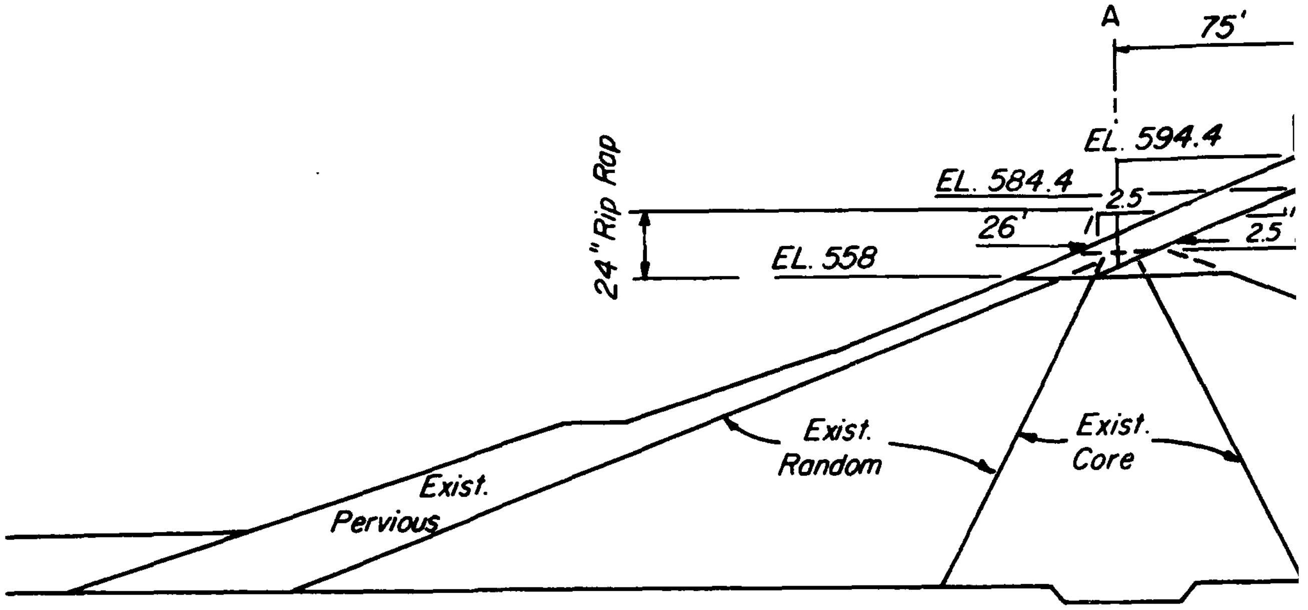
SHEET

PLATE B-115

1

2

U. S. ARMY ENGINEER DISTRICT



TYPICAL SECTIOI

STA. 1+20 TO 24+00

SCALE: 1 IN. = 60 FT.

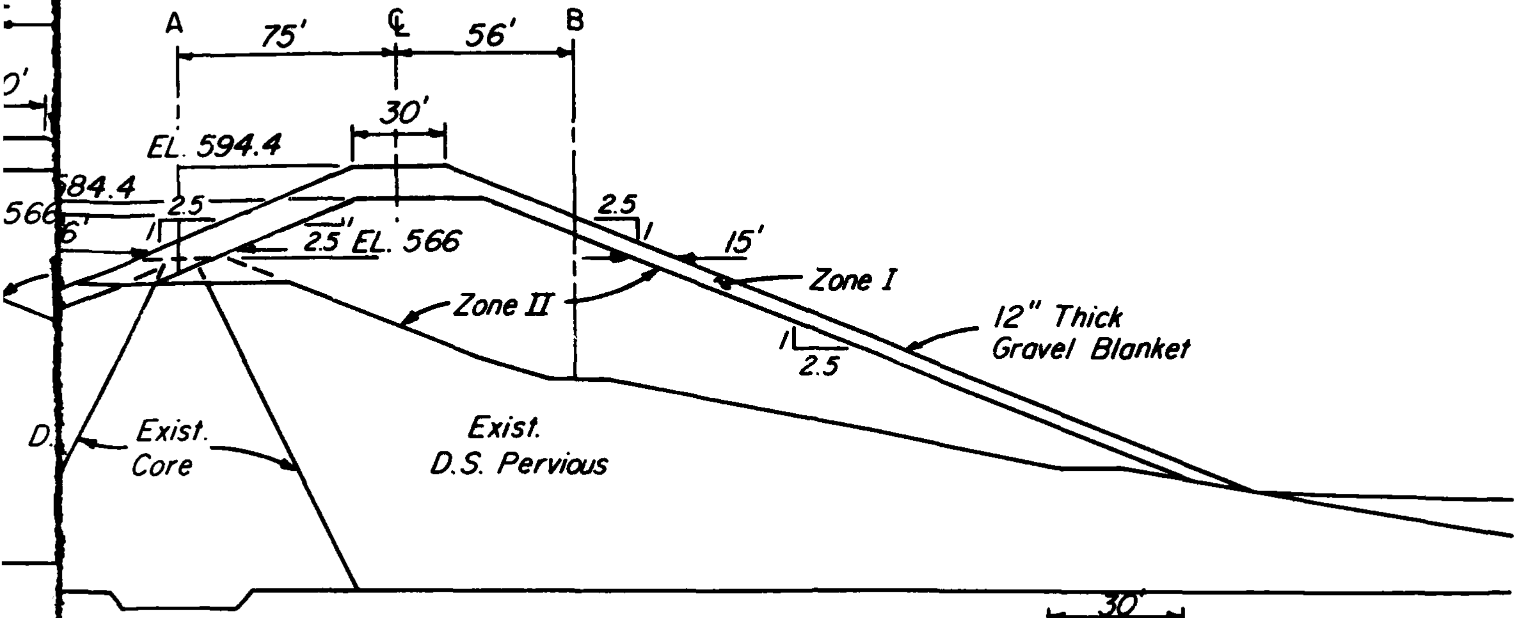
50 0 50 10C

SETTLEMENT MONUMENT LOCATIONS

EXIST. ℄ STA.	SECTION A	 ℄	 B
2+00	X	X	—
2+75	—	X	X
3+50	X	X	—
5+00	X	X	X
7+00	X	X	X
9+00	X	X	X
11+00	X	X	X
13+00	X	X	X
15+00	X	X	X
17+00	X	X	X
19+00	X	X	X
21+00	X	X	X
22+00	—	X	—
23+00	X	X	X

SPECIFICATION REQUIREMEN

MATERIAL	LIFT THICKNESS	COMPACTIVE EFFORT	MOISTU
Zone I	12"	8 Passes 50 T Roller	-2% Opt
Zone II	12"	8 Passes 50 T Roller	-2% Opt +
	8"	8 Passes Tamping Roller	

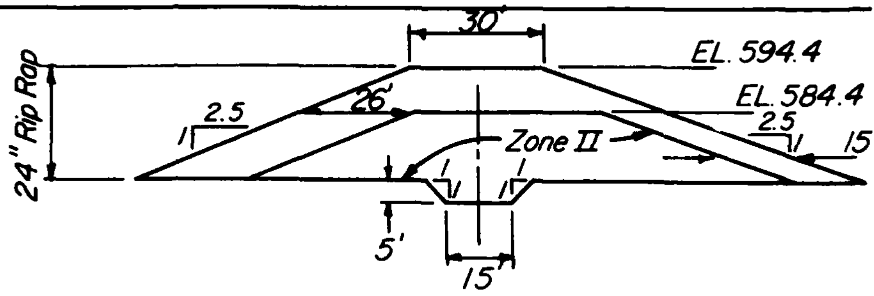


PICAL SECTION

20 TO 24+00

CALE: 1 IN. = 60 FT.

50 100 150



TYPICAL SECTION
EAST OF SPILLWAY

STA. 24+ TO 32+

SCALE: 1 IN. = 40'

50 0 50 100

ION REQUIREMENTS

GR	COMPACTIVE EFFORT	MOISTURE	GRADATION
<2	8 Passes 50 T Roller	-2% Opt +3%	-9" <20% #200
>2	8 Passes 50 T Roller	-2% Opt +3%	-9"
	8 Passes Tamping Roller		-6" >20% #200

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER BASIN, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SETTLEMENT MONUMENT
LOCATIONS & CONSTRUCTION
REQUIREMENTS

DATE APPROVED

SPEC. NO. DACW09-___ B-___

DISTRICT FILE NO.

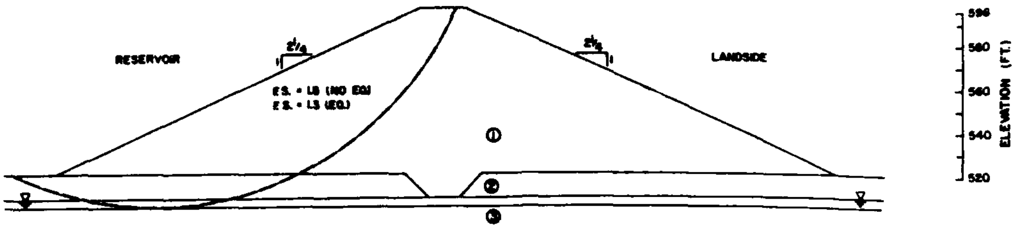
SHEET OF

PLATE B-116

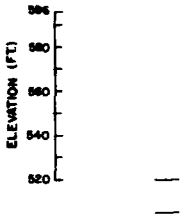
1

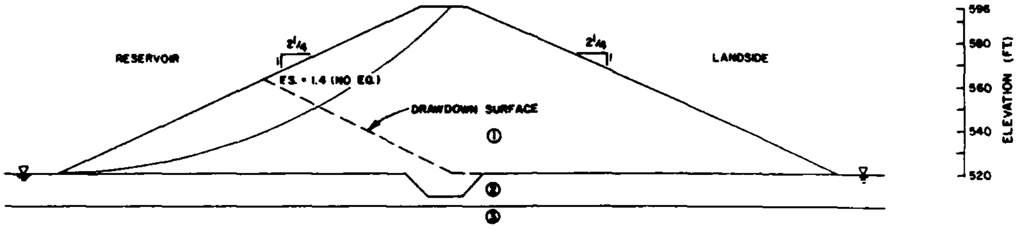
2

VALUE ENGINEERING PAY

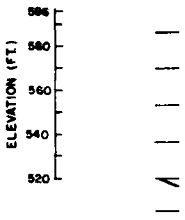


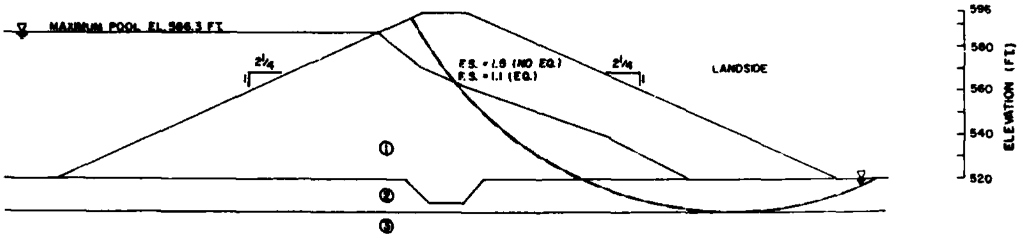
I. END OF CONSTRUCTION



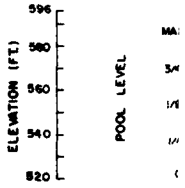


III. SUDDEN DRAWDOWN FROM SPILLWAY CREST





V. STEADY SEEPAGE WITH MAXIMUM POOL (DOWNSTREAM SLOPE)



SUMMARY OF SLOPE STABILITY ANALYSIS

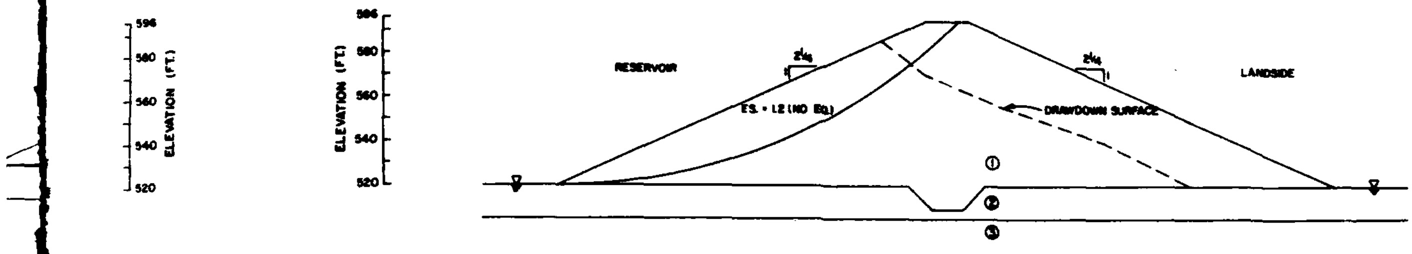
(EM 1110-2-1902, APRIL 1970)

FACTOR OF SAFETY

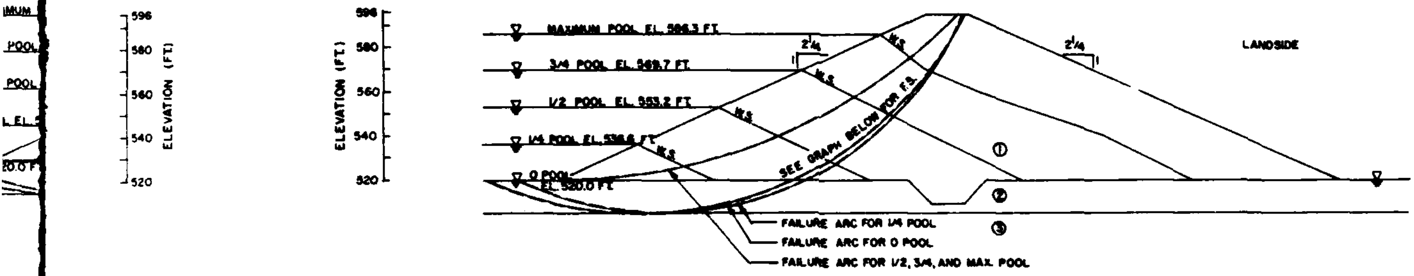
CASE	NO EARTHQUAKE		WITH EARTHQUAKE k = 0.15g	
	MINIMUM	MINIMUM ALLOWABLE	MINIMUM	MINIMUM ALLOWABLE
I. END OF CONSTRUCTION	1.8	1.3	1.3	1.0
II. SUDDEN DRAWDOWN FROM MAXIMUM POOL	1.2	1.0	NA	NA
III. SUDDEN DRAWDOWN FROM SPILLWAY CREST	1.4	1.2	NA	NA
IV. PARTIAL POOL WITH STEADY SEEPAGE	1.7	1.5	1.1	1.0
V. STEADY SEEPAGE WITH MAXIMUM POOL	1.8(1)	1.5	1.1	1.0

(1) MINIMUM FACTOR OF SAFETY BY HAND CALCULATION: F.S. = 1.6

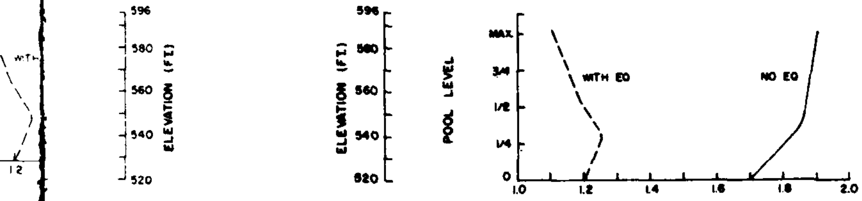
SAFETY PAYS



II. SUDDEN DRAWDOWN FROM MAXIMUM POOL



IV. PARTIAL POOL WITH STEADY SEEPAGE



FACTOR OF SAFETY
(PARTIAL POOL WITH STEADY SEEPAGE)

LEGEND

———	FAILURE ARC WITH NO EARTHQUAKE FORCES
— — —	FAILURE ARC WITH EARTHQUAKE FORCES
WS	WATER SURFACE
EQ	EARTHQUAKE
NA	NOT APPLICABLE

SCALE: 1 IN. = 30 FT.
SCALE 25 0 25 50 75 FEET

SOIL PROPERTIES

MATERIAL	DENSITY		R-STRENGTH		S-STRENGTH		Q-STRENGTH	
	γ_m (pcf)	γ_{sat} (pcf)	ϕ (deg)	C (tsf)	ϕ' (deg)	C' (tsf)	ϕ (deg)	C (tsf)
① EMBANKMENT (SC, BORROW AREA A)	135	139	25	1.20	37	0.0	37	0.0
② SC-CL FOUNDATION	106	120	11	0.85	30	0.1	16	0.5
③ SM FOUNDATION	109	127	30	0.055	34	0.0	34	0.0

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

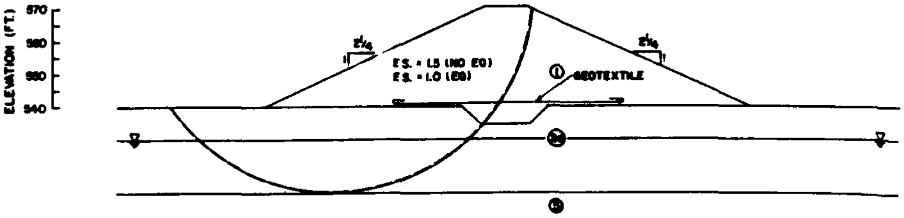
DESIGNED BY:
DRAWN BY:
CHECKED BY:

PRADO DAM
SLOPE STABILITY
AUXILIARY DIKE

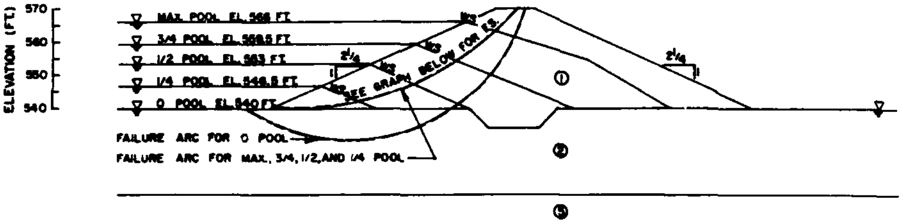
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

1

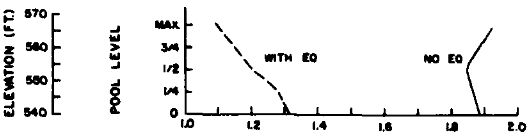
VALUE ENGINEERING P



I END OF CONSTRUCTION



III PARTIAL POOL WITH STEADY SEEPAGE



FACTOR OF SAFETY
(PARTIAL POOL WITH STEADY SEEPAGE)

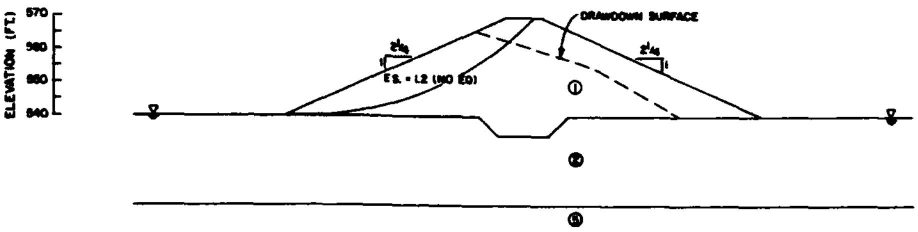
SOIL PROPERTIES

MATERIAL	DENSITY		R-STRENGTH		S-STRENGTH		Q-STRENGTH	
	γ_m (pcf)	γ_{sat} (pcf)	ϕ (deg)	C (tsf)	ϕ' (deg)	C' (tsf)	ϕ (deg)	C (tsf)
① EMBANKMENT (SC-BORROW AREA)*	136	139	25	1.20	37	0	37	0
② CL FOUNDATION – ABOVE WATER TABLE	119	127	15	0.30	NA		16	0.30
– BELOW WATER TABLE	NA	127	15	0.20	30	0.10	4	0.20
③ SM FOUNDATION	108	123	28	0.10	32	0	NA	
RESIDUAL STRENGTHS:								
a. AT TOE					ϕ_{res} = 15°			
b. BETWEEN TOE AND CREST					ϕ_{res} = 28°			
c. BELOW CREST					ϕ_{res} = 32°			
④ SC FOUNDATION	100	120	15	0.25	30	0	10	0.25
⑤ SP-SM FOUNDATION	103	124	32	0.05	35	0	NA	

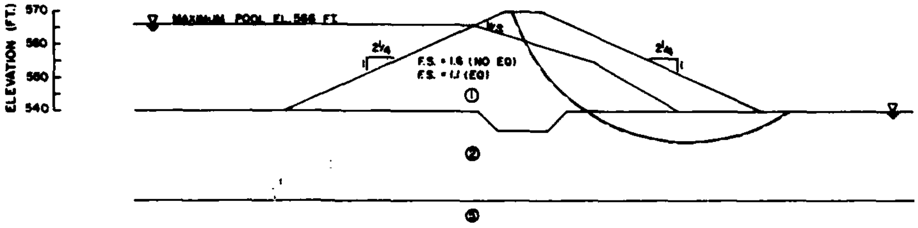
SUMMA

CASE(1
I. END OF CONS
II. SUDDEN DRAW FROM MAXIMU
III. PARTIAL POOL STEADY SEEP
IV. STEADY SEEPA MAXIMUM POO STREAM SLOP
V. POST-EARTHQ

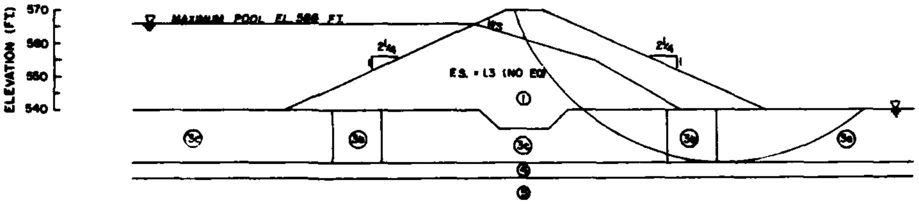
(1) CALCULATED 1
SHOWN ON TH
(2) MINIMUM FACTO
(3) CASE I IS ONL
CASES MEET M
GEOTEXTILE.



II SUDDEN DRAWDOWN FROM MAXIMUM POOL



IV STEADY SEEPAGE WITH MAXIMUM POOL (DOWNSTREAM SLOPE)



V POST-EARTHQUAKE

SUMMARY OF SLOPE STABILITY ANALYSIS

(EM 1110-2-1902, APRIL 1972)

FACTOR OF SAFETY

CASE(3)	NO EARTHQUAKE		WITH EARTHQUAKE k = 0.15g	
	CALCULATED(1)	MINIMUM ALLOWABLE	CALCULATED(1)	MINIMUM ALLOWABLE
I. END OF CONSTRUCTION	1.5	1.3	1.0	1.0
II. SUDDEN DRAWDOWN FROM MAXIMUM POOL	1.2	1.0	NA	NA
III. PARTIAL POOL WITH STEADY SEEPAGE	1.9	1.5	1.1	1.0
IV. STEADY SEEPAGE WITH MAXIMUM POOL (DOWNSTREAM SLOPE)	1.6(2)	1.5	1.1	1.0
V. POST-EARTHQUAKE	1.3	1.0	NA	NA

(1) CALCULATED FACTORS OF SAFETY CORRESPOND TO FAILURE ARCS SHOWN ON THIS PLATE.

(2) MINIMUM FACTOR OF SAFETY BY HAND CALCULATION: F.S. = 1.6

(3) CASE I IS ONLY CASE ANALYZED WITH GEOTEXTILE. ALL OTHER CASES MEET MINIMUM ALLOWABLE FACTOR OF SAFETY WITHOUT GEOTEXTILE.

LEGEND

———	FAILURE ARC WITH NO EARTHQUAKE FORCES.
— — —	FAILURE ARC WITH EARTHQUAKE FORCES (SEISMIC COEFFICIENT = 0.15g).
EQ	EARTHQUAKE
NA	NOT APPLICABLE
WS	WATER SURFACE

SCALE: 1 IN. = 20 FT.

SCALE 10 0 10 20 30 40 50 FEET

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:
PPhilbrick

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SLOPE STABILITY
DIKE AT ALCOA ALUMINUM PLANT

SUBMITTED BY:

DATE APPROVED:

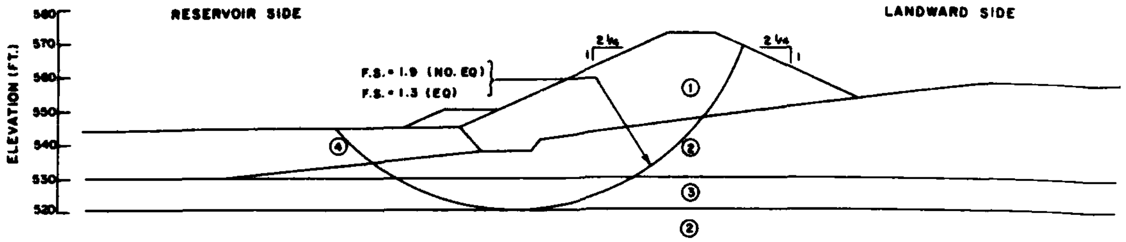
SPEC. NO. DACW09-____ B-____

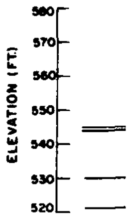
DISTRICT FILE NO.

SHEET

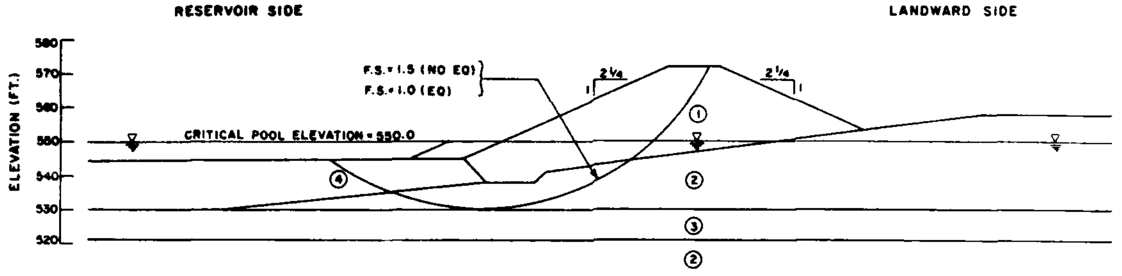
1

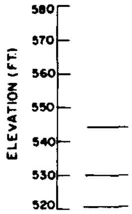
2





I END OF CONSTRUCTION





III PARTIAL POOL WITH STEADY SEEPAGE

SUMMARY OF SLOPE STABILITY ANALYSIS

(REF: EM1110-2-1902, APRIL 1970)

FACTOR OF SAFETY

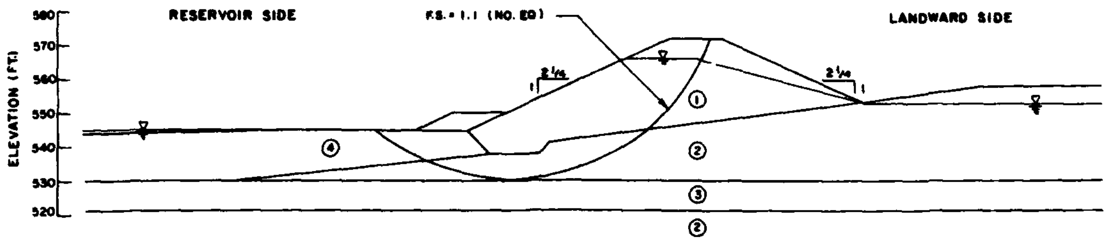
CASE	NO EARTHQUAKE		WITH EARTHQUAKE K=0.15g	
	MINIMUM	MINIMUM ALLOWABLE	MINIMUM	MINIMUM ALLOWABLE
I END OF CONSTRUCTION	1.9	1.3	1.3	1.0
II SUDDEN DRAWDOWN FROM MAXIMUM POOL	1.1	1.0	—	—
III PARTIAL POOL WITH STEADY SEEPAGE	1.5*	1.5	1.0	1.0
IV STEADY SEEPAGE WITH MAXIMUM POOL	1.6	1.5	1.1	1.0

*MINIMUM FACTOR OF SAFETY CALCULATED BY HAND: F.S = 1.5

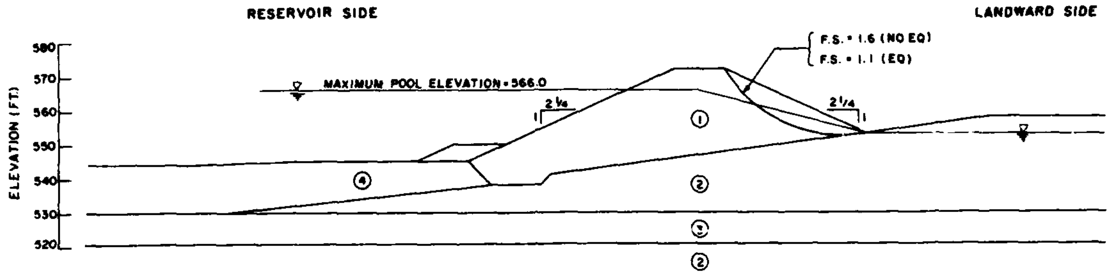
SOIL PROPERTIES

MATERIAL	DENSITY		R-STRENGTH		S-STRENGTH		Q-STRENGTH	
	γ_m (pcf)	γ_{sat} (pcf)	Ø (deg)	C (tsf)	Ø' (deg)	C' (tsf)	Ø (deg)	C (tsf)
① EMBANKMENT	135	139	25	1.20	37	0.0	37	0.0
② CH, FOUNDATION	105	114	14	0.18	31	0.0	7	1.0
③ CL-ML FOUNDATION	127	130	31.5	0.4	38	0.0	0.0	0.35
④ MH/OH FOUNDATION	85	87	13	0.2	15	0.0	9	0.12

ALUE ENGINEERING PAYS



II SUDDEN DRAWDOWN FROM MAXIMUM POOL



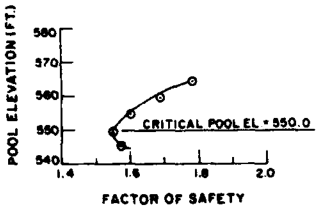
IV STEADY SEEPAGE WITH MAXIMUM POOL (DOWNSTREAM SLOPE)

LEGEND

F.S.	FACTOR OF SAFETY
EQ.	EARTHQUAKE WITH SEISMIC COEFFICIENT = 0.15g
⊽	PHREATIC SURFACE

RTIES

RENGTH	S-STRENGTH		Q-STRENGTH	
C (tsf)	Ø' (deg)	C' (tsf)	Ø (deg)	C (tsf)
1.20	37	0.0	37	0.0
0.18	31	0.0	7	1.0
0.4	38	0.0	0.0	0.35
0.2	15	0.0	9	0.12



PARTIAL POOL WITH STEADY SEEPAGE

SCALE: 1 IN = 20 FT.

10 0 10 20 30 40 50

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY: LBA

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SLOPE STABILITY

DIKE AT CALIFORNIA INSTITUTION FOR WOMEN

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09-____ B-____

DISTRICT FILE NO.

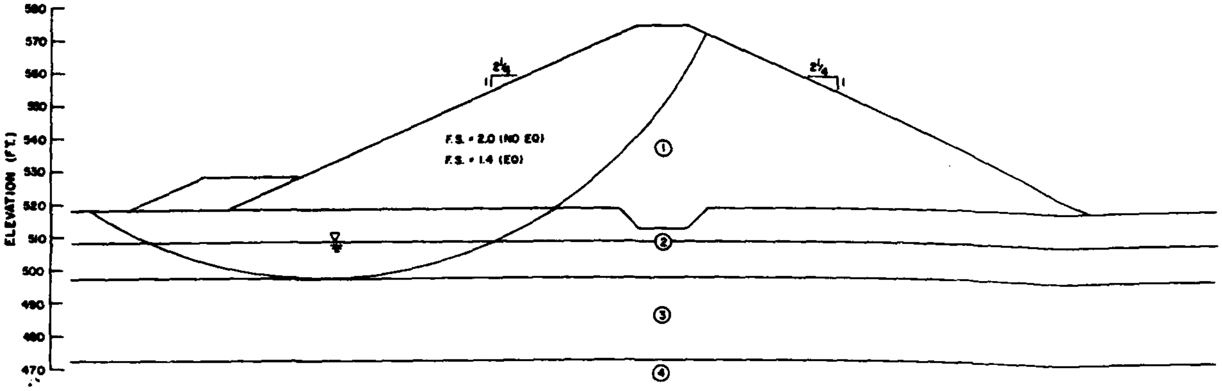
SHEET

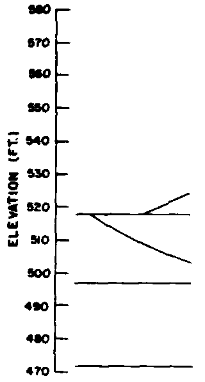
PLATE B-119

SAFETY PAYS

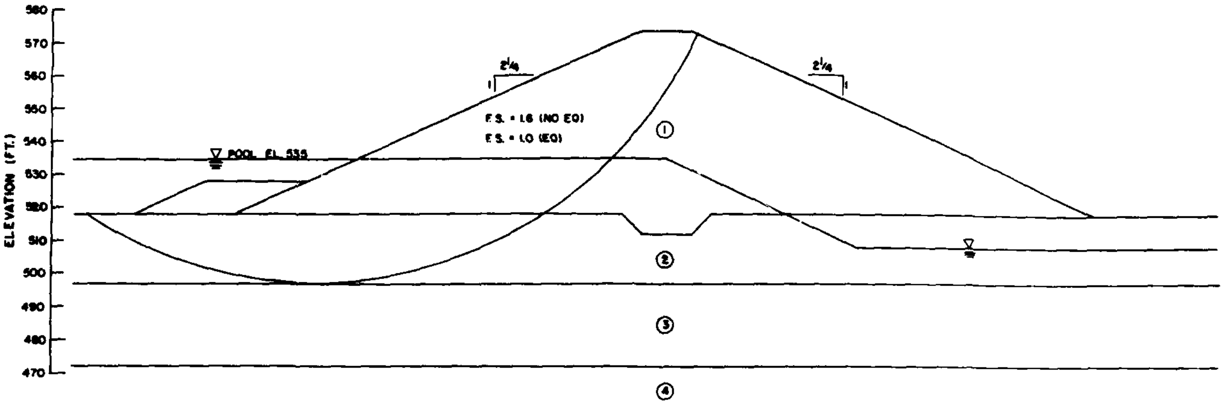
2

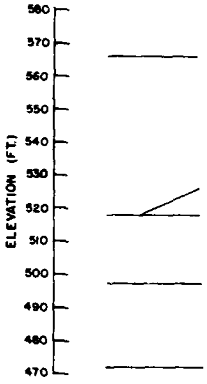
VALUE ENGINEERING I





I. END OF CONSTRUCTION





III. PARTIAL POOL WITH STEADY SEEPAGE

SUMMARY OF SLOPE STABILITY ANALYSIS
(REF: EM 1110-2-1902, APRIL 1970)

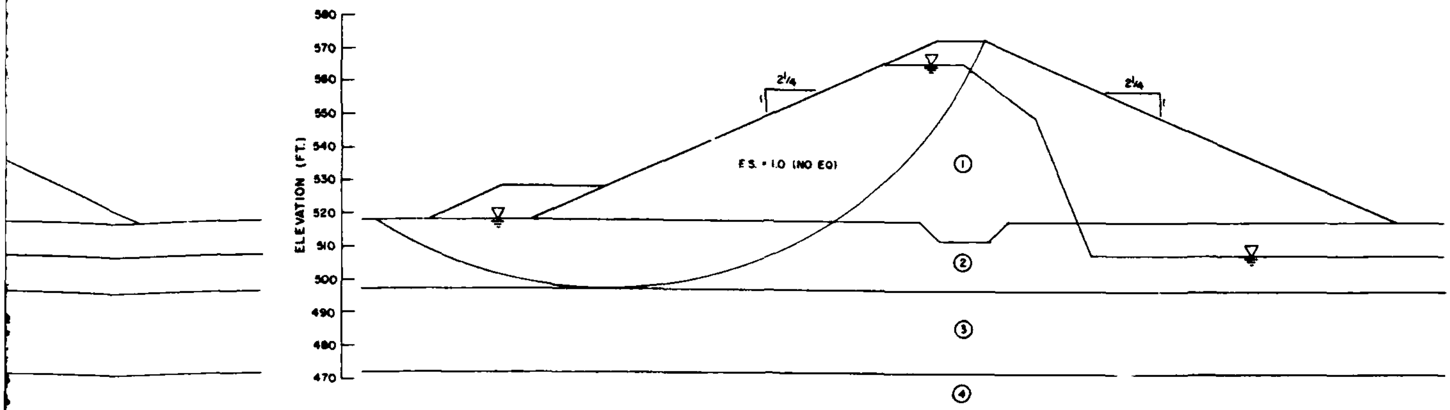
FACTOR OF SAFETY

CASE	NO EARTHQUAKE		WITH EARTHQUAKE K = 0.15g	
	MINIMUM	MINIMUM ALLOWABLE	MINIMUM	MINIMUM ALLOWABLE
I. END OF CONSTRUCTION	2.0	1.4	1.4	1.0
II. SUDDEN DRAWDOWN FROM MAXIMUM POOL	1.0	1.0	NA	NA
III. PARTIAL POOL WITH STEADY SEEPAGE	1.6	1.5	1.1	1.0
IV. STEADY SEEPAGE WITH MAXIMUM POOL	1.5*	1.5	1.0	1.0

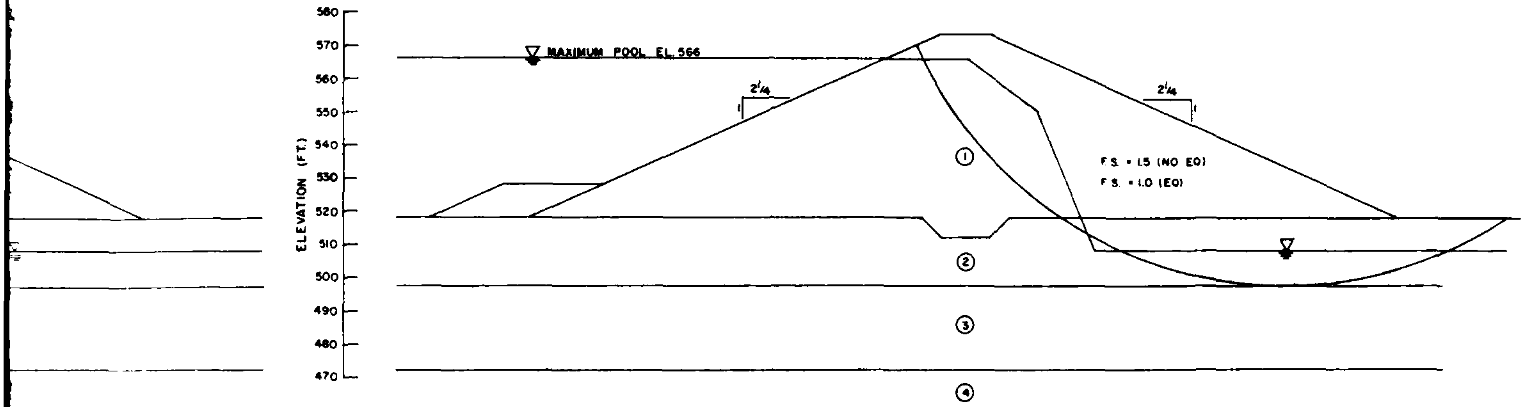
* MINIMUM FACTOR OF SAFETY CALCULATED BY HAND; F.S. = 1.5

SOIL PROPERTIES

MATERIAL	DENSITY		R-STRENGTH		S-STRENGTH		Q-STRENGTH	
	γm (pcf)	γsat (pcf)	Ø (deg)	C (tsf)	Ø' (deg)	C' (tsf)	Ø (deg)	C (tsf)
① EMBANKMENT (SC, BORROW AREA #1)	135	139	25	1.20	37	0.0	37	0.0
② CL FOUNDATION	119	126.5	14	0.10	31	0.0	17	0.3
③ SM #1 FOUNDATION	–	135	33	0.75	35	0.0	–	–
④ SM #2 FOUNDATION	115	120	22	0.35	32	0.0	–	–



II. SUDDEN DRAWDOWN FROM MAXIMUM POOL



IV. STEADY SEEPAGE WITH MAXIMUM POOL (DOWNSTREAM SLOPE)

LEGEND

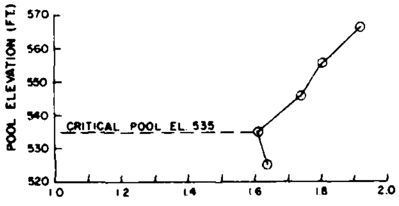
F.S.	FACTOR OF SAFETY.
EQ	EARTHQUAKE WITH SEISMIC COEFFICIENT = 0.15g.
▽	PHREATIC SURFACE
NA	NOT APPLICABLE

SCALE: 1 IN = 20 FT.

SCALE 10 0 10 20 30 40 50 FEET

SOIL PROPERTIES

DENSITY		R-STRENGTH		S-STRENGTH		Q-STRENGTH	
γm (pcf)	γsat (pcf)	Ø (deg)	C (tsf)	Ø' (deg)	C' (tsf)	Ø (deg)	C (tsf)
135	139	25	1.20	37	0.0	37	0.0
119	126.5	14	0.10	31	0.0	17	0.3
–	135		0.75	35	0.0	–	–
115	120	22	0.35	32	0.0	–	–



PARTIAL POOL WITH STEADY SEEPAGE

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

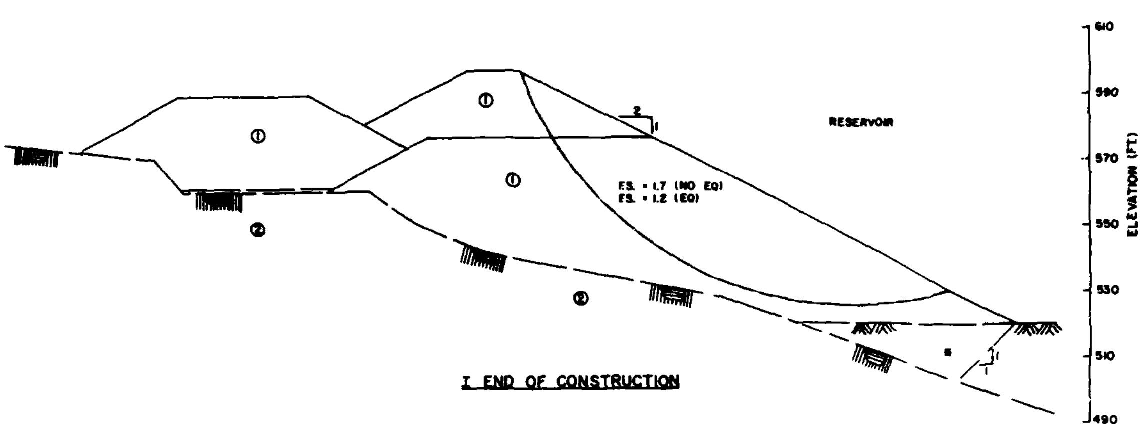
SLOPE STABILITY
DIKE AT CORONA SEWAGE TREATMENT PLANT

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-___
DISTRICT FILE NO.
SHEET

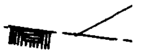
PLATE B-

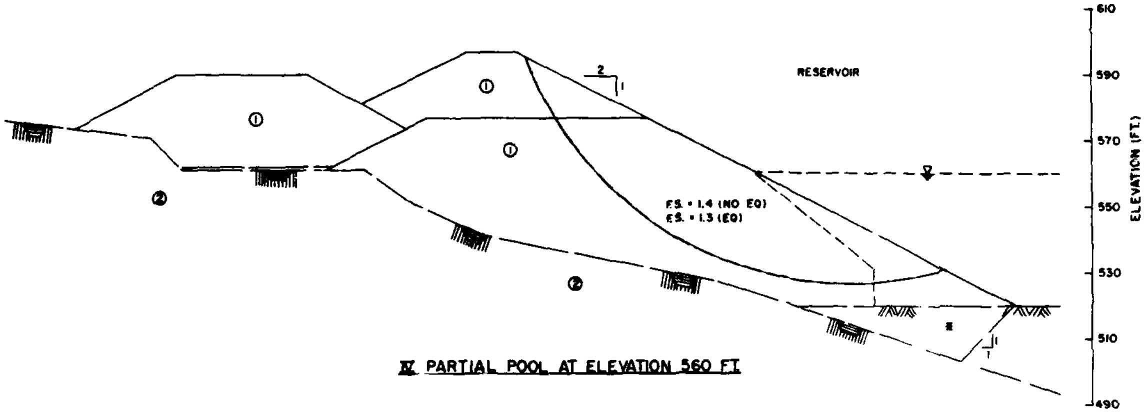
1

2

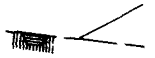


I END OF CONSTRUCTION





III PARTIAL POOL AT ELEVATION 560 FT



SUMMARY OF SLOPE STABILITY ANALYSIS

(EM 1110-2-1902, APRIL 1970)

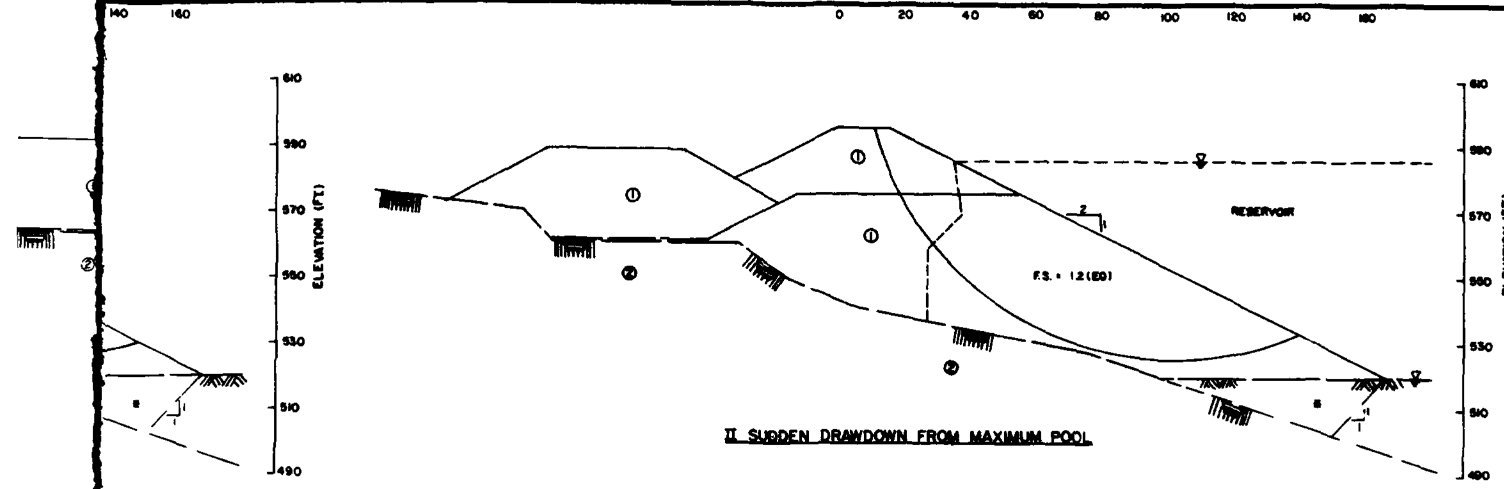
FACTOR OF SAFETY

CASE	NO EARTHQUAKE		WITH EARTHQUAKE k = 0.15g	
	CALCULATED	MINIMUM ALLOWABLE	CALCULATED	MINIMUM ALLOWABLE
I END OF CONSTRUCTION	1.7	1.3	1.2	1.0
II SUDDEN DRAWDOWN FROM MAXIMUM POOL	1.2	1.0	NA	NA
III PARTIAL POOL AT ELEVATION 560 FT.	1.4	1.4	1.3	1.0
IV PARTIAL POOL AT ELEVATION 570 FT.	1.5	1.4	1.2	1.0

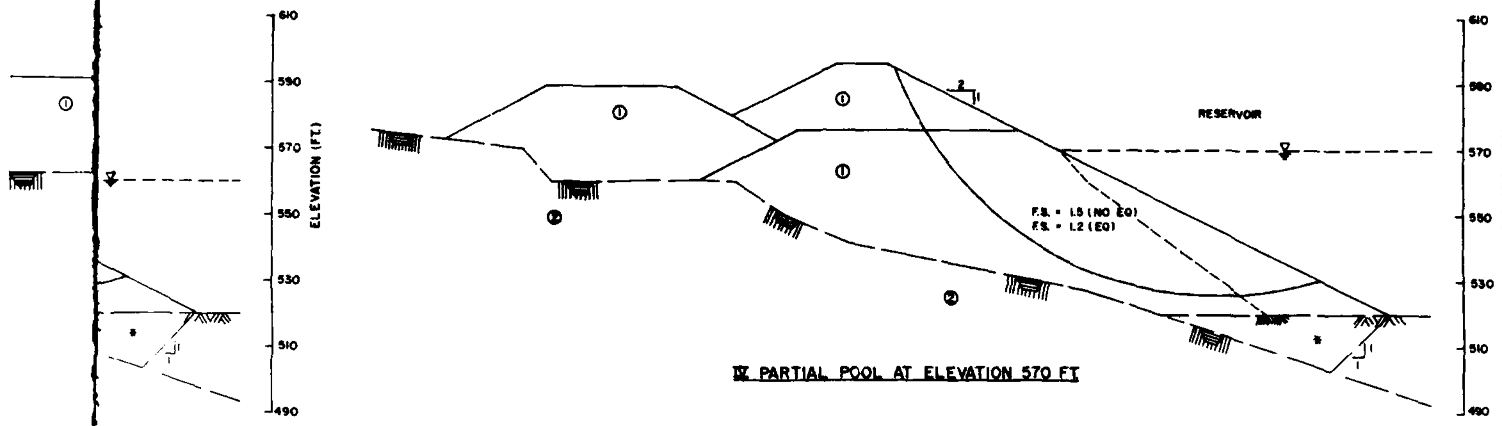
SOIL PROPERTIES

MATERIAL	UNIT WEIGHT		R-STRENGTH	
	γ_m (pcf)	γ_{sat} (pcf)	ϕ (deg)	C (tsf)
① EMBANKMENT (CL, BORROW #2)	124	120	16	0.4
② FOUNDATION (BEDROCK)	130	NA	NA	NA

YS VALUE ENGINEERING PAYS



II SUDDEN DRAWDOWN FROM MAXIMUM POOL



IV PARTIAL POOL AT ELEVATION 570 FT

LEGEND

———	FAILURE ARC WITH NO EARTHQUAKE FORCES.
– – – –	FAILURE ARC WITH EARTHQUAKE FORCES.
∇	WATER SURFACE
EQ	EARTHQUAKE
NA	NOT APPLICABLE
*	TO BE EXCAVATED AND REPLACED WITH EMBANKMENT MATERIAL ①

ENGTH
C' (tsf)
0
0.5

SOIL PROPERTIES

MATERIAL	UNIT WEIGHT		R-STRENGTH		S-STRENGTH	
	γ_m (pcf)	γ_{sat} (pcf)	ϕ (deg)	C (tsf)	ϕ' (deg)	C' (tsf)
① EMBANKMENT (CL, BORROW #2)	124	120	16	0.4	30	0
② FOUNDATION (BEDROCK)	130	NA	NA	NA	34	0.5

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929.

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM

SLOPE STABILITY
DIKE AT CORONA EXPRESSWAY

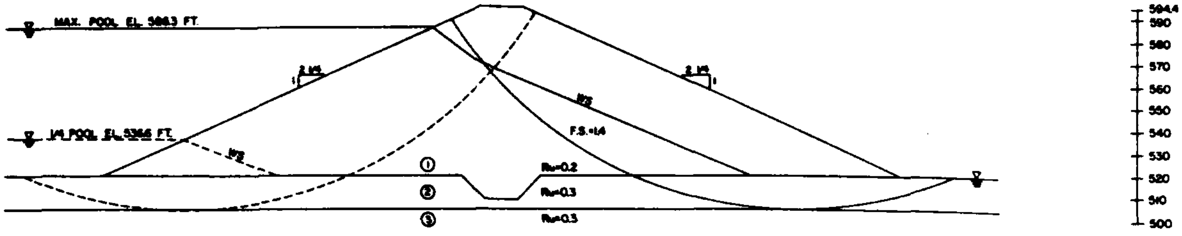
SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
SHEET

SCALE: 1 IN. = 20 FT.
SCALE: 10 0 10 20 30 40 50 FEET

PLATE B-121

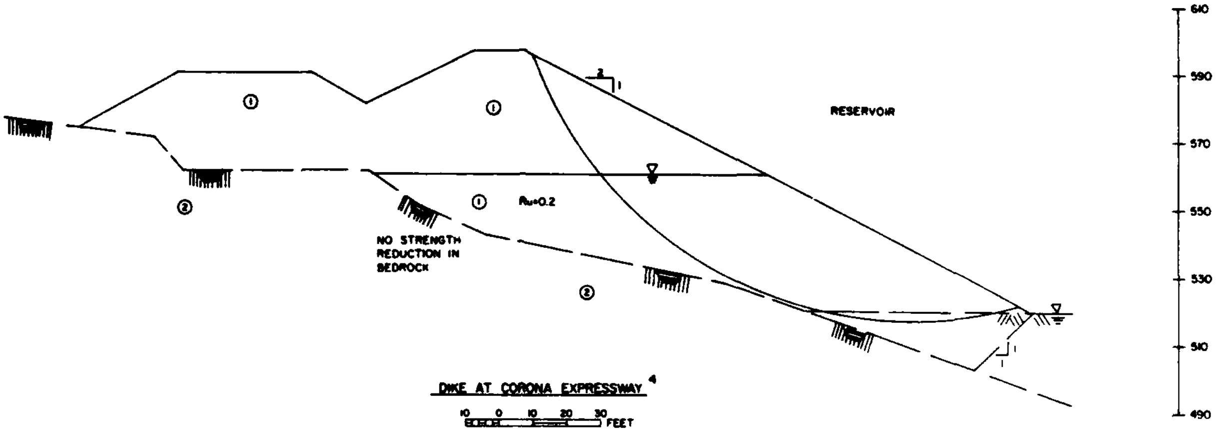
SAFETY PAYS
1

2



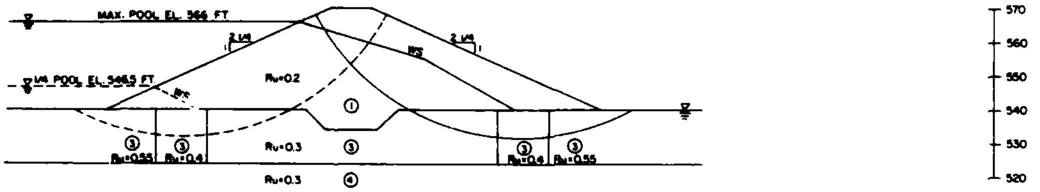
AUXILIARY DIKE [4]

25 0 25 FEET



DIKE AT CORONA EXPRESSWAY [4]

10 0 10 20 30 FEET



DIKE AT ALCOA ALUMINUM PLANT [4]

10 0 10 20 30 FEET

EARTHQUAKE DEFORMATION

RESULTS OF DEFORMATION ANALYSES

DIKE	BASE ACCELERATION [1] (g)		SLOPE, POOL CONDITIONS	YIELD [2] ACCELERATION Ky (g)	ESTIMATED MAXIMUM DISPLACEMENT [3] (inches)	
	LOCAL	REGIONAL			LOCAL	REGIONAL
AUXILIARY	0.6	0.3	DS, MAX. POOL US, 1/4 POOL	0.13 0.25	8 2	2 –
CORONA EXPRESSWAY	0.6	0.3	US, POOL EL. 570	0.14	5	18
ALCOA ALUMINUM PLANT	0.6	0.3	DS, MAX. POOL US, 1/4 POOL	0.13 0.22	4 1	1 –

RESUL.'S OF POST EARTHQUAKE ANALYSES

DIKE	FACTOR OF SAFETY [2]
AUXILIARY	1.4
CORONA EXPRESSWAY	1.3
ALCOA ALUMINUM PLANT	1.5

NOTES:

1 BASE ACCELERATION

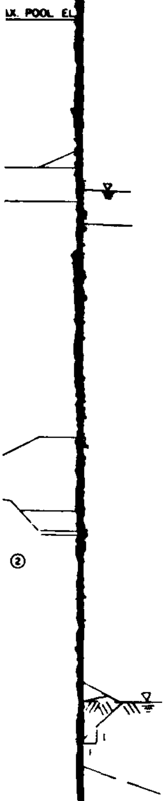
2. A TOTAL STRESS S
WAS USED TO DETER
FAILURE ARCS AND

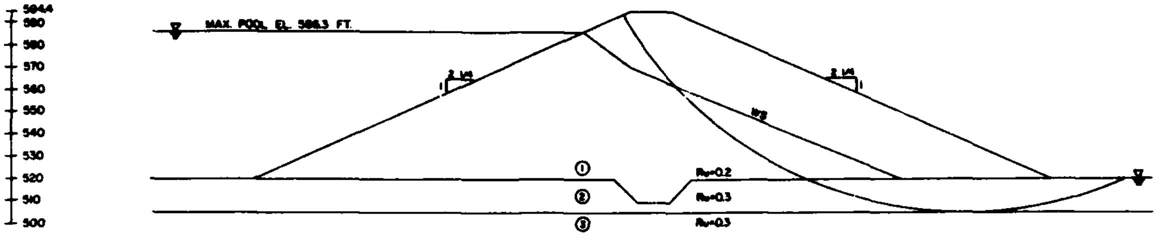
3. DISPACEMENTS ARE

4. SEE PLATES 8-117, 8
ALCOA ALUMINUM PL

PAY

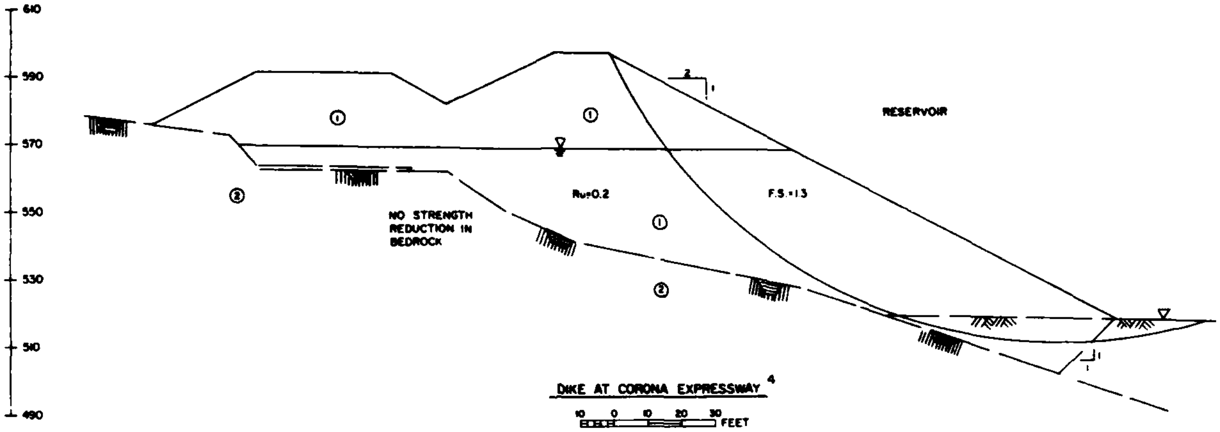
VALUE ENGINEERING PAYS





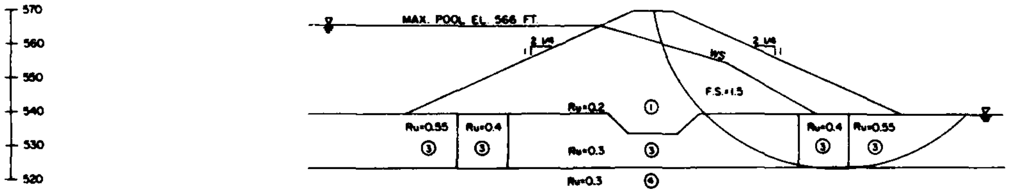
AUXILIARY DIKE

25 0 25 FEET



DIKE AT CORONA EXPRESSWAY 4

10 0 10 20 30 FEET



DIKE AT ALCOA ALUMINUM PLANT 4

10 0 10 20 30 FEET

POST-EARTHQUAKE

AL AND REGI E ANALYSES

BILITY ANAL
AND POST
SSURE RATIO

R OF SAFETY [2]
1.4
1.3
1.5

METHOD FR

B-121 FOR L
CORONA EX

NOTES:

1 BASE ACCELERATION FOR LOCAL AND REGIONAL EVENTS ARE TAKEN FROM TABLE B-2.

2. A TOTAL STRESS SLOPE STABILITY ANALYSIS UTILIZING COMPUTER PROGRAM UTEXAS2 WAS USED TO DETERMINE Ky AND POST EARTHQUAKE FACTORS OF SAFETY. CORRESPONDING FAILURE ARCS AND PORE PRESSURE RATIOS ARE SHOWN ON THIS PLATE.

3. DISPLACEMENTS ARE BASED ON METHOD FROM MAKDISI AND SEED (1979).

4. SEE PLATES B-117, B-118, AND B-121 FOR LEGEND AND SOILS PROPERTIES OF THE AUXILIARY, ALCOA ALUMINUM PLANT, AND CORONA EXPRESSWAY DIKES, RESPECTIVELY.

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
POST-EARTHQUAKE AND DISPLACEMENT ANALYSES
AUXILIARY DIKE, DIKES AT CORONA EXPRESSWAY
AND ALCOA ALUMINUM PLANT

SUBMITTED BY:

DATE APPROVED:

SPEC. NO. DACW09- ____ B- ____

DISTRICT FILE NO.

SHEET

PLATE B-121A

SAFETY PAYS

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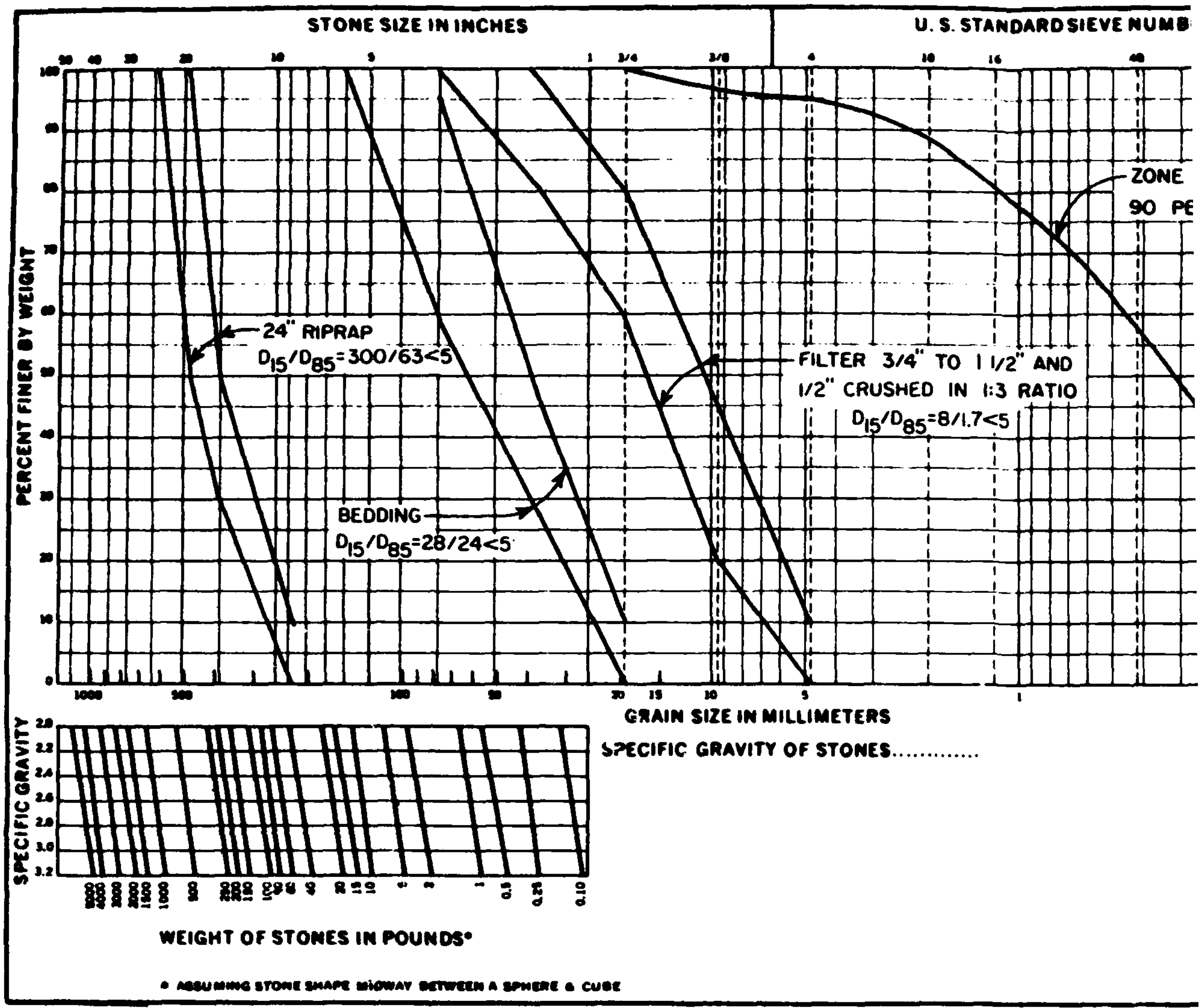
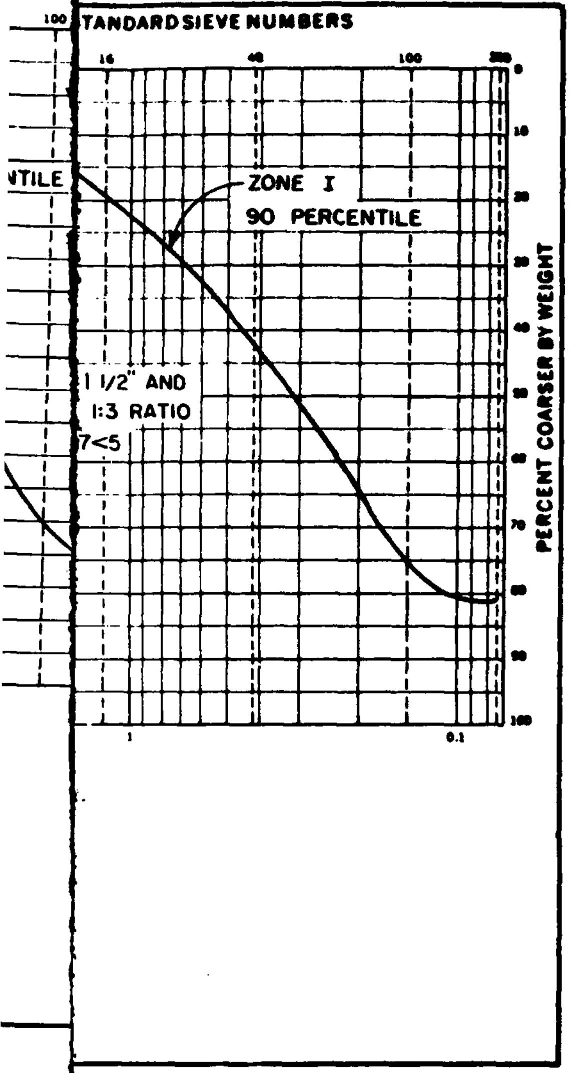
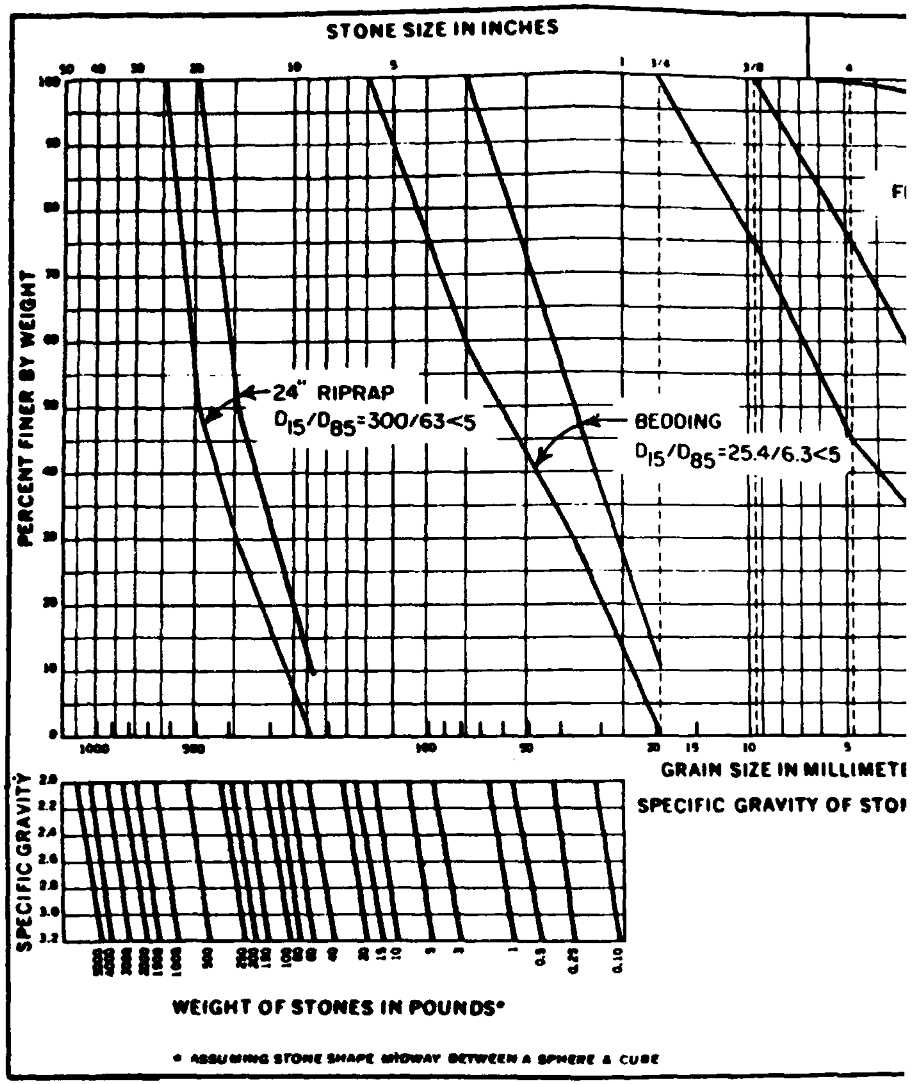


ENG FORM 4056
APR 67

PRADO DAM SLOPE PROTECTION
EL. 558 TO 594.4





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CORONA EXPRESSWAY SLOPE
FOR FINE GRAINED

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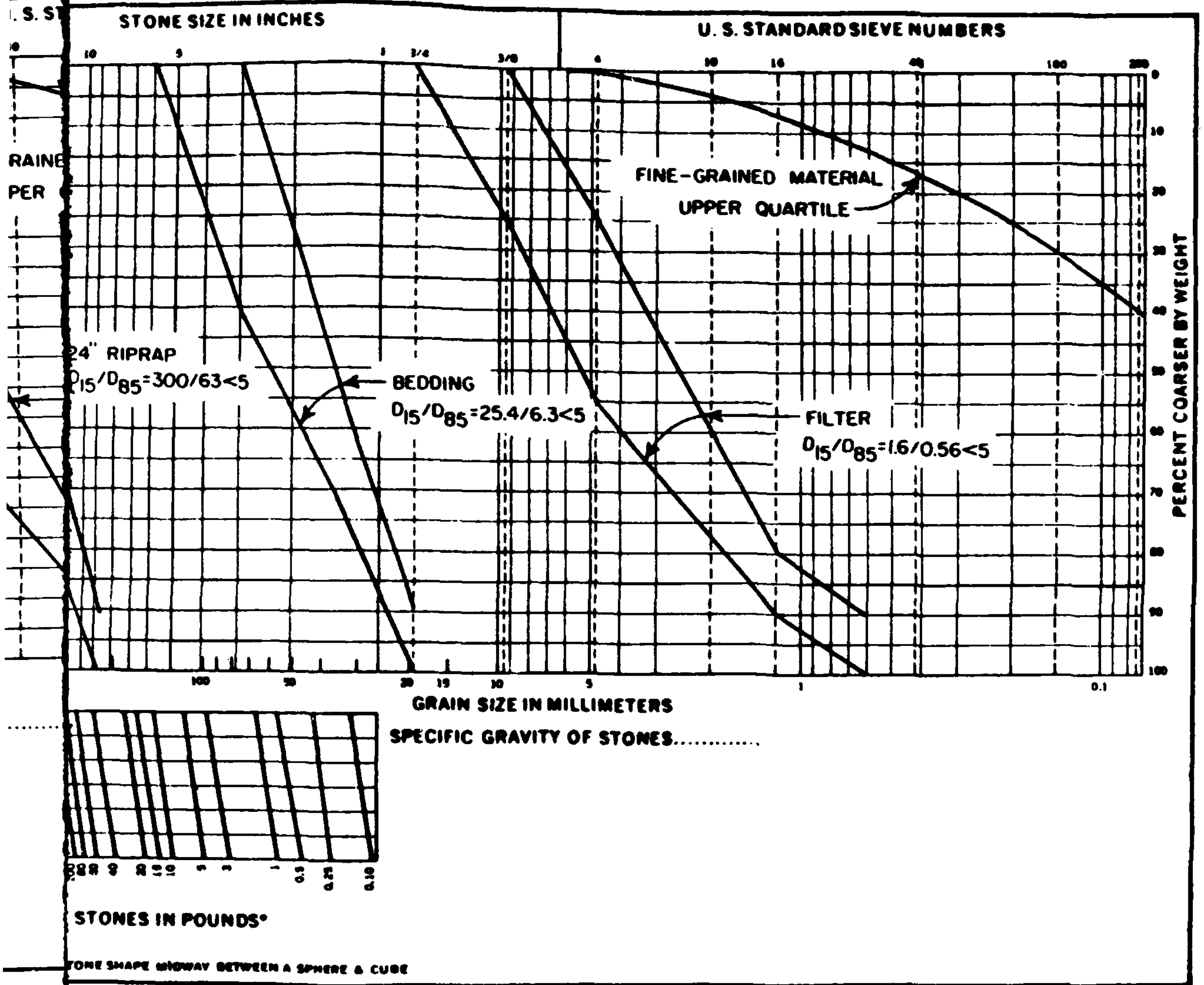

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CORONA EXPRESSWAY SLOPE PROTECTION FOR FINE GRAINED FILL

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM
PRADO DAM

SLOPE PROTECTION GRADATIONS

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW 09-____ B-____
SHEET
DISTRICT FILE NO.

PLATE B-122

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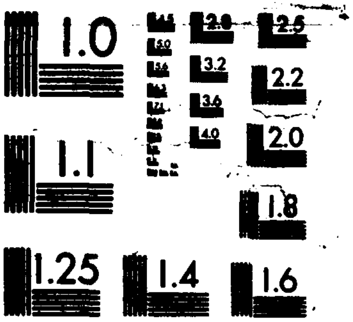

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I. ALTERNATIVE INVESTIGATIONS AND COORDINATION

General

1-01 In November 1986, representatives of South Pacific Division (SPD), North Pacific Division (NPD), Los Angeles District (SPL), and Portland District (NPP), met in San Francisco, California, to discuss the Santa Ana Project and the possibility of design participation by NPP. SPL asked that NPP consider general design memorandum (GDM) level design work for the following four project elements: Santiago Creek Drain, Oak Street Drain, Prado Dam, and Seven Oaks Dam. At that time, it was agreed that NPP would evaluate its ability to take on all or part of the subject design work. In subsequent discussions, NPP agreed to perform the following specialized design in support of Phase II GDM level design: Seven Oaks Dam outlet works, Seven Oaks dam break analysis and overflow delineation, and Prado Dam outlet works. On 16 and 17 December 1986, SPL and NPP staff members met in Los Angeles to discuss NPP involvement in the Santa Ana Project and to visit the project sites. At that time, it was agreed that NPP would prepare four conceptual designs for the regulating outlet works at Prado Dam. Those alternatives were: cut and cover conduits through the spillway crest; cut and cover conduits through the spillway right abutment; outlet tunnels through the embankment left abutment; and cut and cover conduits through the embankment dam left abutment. It was also agreed that a decision would be made on which alternative to carry forward into more intense design when the conceptual design evaluation was presented. During the month of January 1987, the NPP technical design team visited the Prado Dam site, the Memorandum of Understanding (MOU) and Scopes of Work (SOW) were negotiated and finalized, and cost estimates for the NPP effort were prepared, negotiated, refined, and agreed upon. The final MOU was signed by the Chiefs of Engineering of all four Corps offices, SPL, NPD, SPL, and NPP, between 5 February 1987 and 3 March 1987.

Conceptual Design Meeting

1-02 On 2 March 1987, representatives of the technical staffs from SPL and NPP met in Los Angeles to review various conceptual designs developed by NPP for the outlet works at Prado Dam. On 3 March 1987, a meeting with technical and management staff members from the Office of the Chief of Engineers (OCE), SPD, SPL, and NPP was conducted to present the conceptual alternatives, review and comment on those alternatives, and concur upon a preferred concept.

CONCEPTS AND ALTERNATIVES

1-03 NPP investigated the four conceptual alternatives listed below:

(1) Alternative I, spillway crest alignment - cut and cover conduits.

(2) Alternative II, spillway right abutment alignment - cut and cover conduits.

(3) Alternative III, embankment dam left abutment alignment - outlet tunnels.

  (a) Alternative IIIa, dual towers.

  (b) Alternative IIIb, single tower.

(4) Alternative IV, embankment dam left abutment alignment - cut and cover conduits.

  (a) Alternative IVa, dual towers.

  (b) Alternative IVb, single tower.

GENERAL DESIGN ASSUMPTIONS

1-04 The following is a list of the general design assumptions used by NPP in its evaluation. Assumptions used in each technical specialty are discussed later.

(1) Trash boom across intake channel. (See paragraph 8-07.)

(2) Intake trash openings = 2/3 (gate width). (Ref. EM 1110-2-2400.)

(3) Diversion through existing regulating outlet (RO) works. (See paragraph 10-01.)

(4) Minimal cofferdam required. (See paragraph 10-01.)

(5) Maintenance bulkheading required. (See paragraph 4-16.)

(6) Service gate - no emergency gate.(Ref. EM 1110-2-2400.)

(7) Maintenance deck access required. (See paragraph 2-05.)

(8) Lined downstream channel. (See paragraph 3-16.)

(9) Architectural features required. (See paragraph 2-12.)

ISSUES

1-05 Following NPP's presentation of the conceptual analyses, including advantages, disadvantages, and costs, the meeting was opened to discussion and comment. Several issues were identified and discussed. The following is a list of the key issues raised:

(1) Choice of alignment restrictions due to topography and congestion of the freeway along the embankment dam right abutment.

(2) Diversion and control of water during construction.

(3) Concern about contraction joints subjected to high pressures.

COMPARISON OF ALTERNATIVES

1-06 The advantages and disadvantages of each of the alternatives were presented at the conceptual design meeting. The material presented follows:

Alternative	Advantages	Disadvantages
I. Spillway crest alignment - cut and cover conduits.	Less open cut excavation.	Tower located in spillway approach. Spillway slab and crest excavation required. Long/flatter sloped conduits require large cross- areas. Conduit curves/downstream exit channel alignment hydraulically unacceptable. Difficult energy dissipation layout.
II. Spillway right abutment alignment - cut and cover conduits.	Possible excavation decreases in conjuntion with spillway modifications.	Tower interfers with spillway approach. Long/flatter sloped conduits require large cross-sectional areas. Conduit curves hydraulically unacceptable. Increased excavation for tower and stilling basin.
III. Embankment dam left abutment alignment - outlet tunnels.	Tower location out of spillway approach. Hydraulically short and straight tunnels. Good downstream channel alignment. Less disturbance to area. No backfill problems. Less excavation quantities.	Little rock cover. Possible seepage path along tunnel/rock contact. Larger tower required. Short tunnel construction. Higher risk of construction problems. Potential settlement/seepage path cracks above tunnels. Large excavation and support system for portals. Tunneling requires specialized equipment.

Alternative	Advantages	Disadvantages
IV. Embankment dam left abutment align-alignment - cut and cover conduit.	Tower location out of spillway approach. Hydraulically short and straight tunnels. Good downstream channel alignment. Smaller intake structure. Less mobilization and demobilization time. Less risk of major construction problems. Backfill compatibility with embankment. Less costly.	Greater excavation and disturbance area. Possibility of longitudinal ment cracking and seepage paths. Longer, More complicated transition.

RECOMMENDATION

1-07 NPP recommended the cut and cover alternative through the embankment dam left abutment. The major advantages of this alternative are that it has the lowest cost, least risk of construction problems in comparison with the other alternatives, and provides good alignment with the downstream channel. At the conclusion of the discussions, the group agreed with the recommended alternative.

Refinement of Alternative Analysis

1-08 During the period March through early June 1987, NPP continued to refine the outlet works design and communicated almost daily with SPL to assure concurrence on design issues. NPP completed GDM level design of the RO conduit, stilling basin walls, and slab in early May 1987. During May, NPP confirmed the tower stability, pier thicknesses, transition, and trash strut design. As presented at the conceptual design meeting, NPP redesigned the downstream channel from the existing drop structure upstream to the channel proposed in this report.

On-Board Review Meeting

1-09 On 9 June 1987, representatives of the technical and management staffs from SPL and NPP met in Portland. The purpose of the meeting was to present and review the design status. In addition to design status, NPP presented updated design criteria and assumptions, cost estimates, and construction schedules.

DISCUSSION AND ACTIONS REQUIRED

1-10 Several issues were discussed following the formal presentation. In addition, informal technical counterpart meetings were held during which several issues were resolved. The following is a list of the major actions required as a result of those discussions:

(1) NPP to add trashracks for low flow intakes.

(2) NPP to evaluate the location of gate controls.

(3) NPP to address the need for modeling.

(4) NPP to evaluate bulkhead additions near the downstream end of the splitter wall.

(5) NPP to evaluate the need for backfill over the last few hundred feet of the cut and cover conduit as a possible cost saving item.

(6) NPP to clarify the gate sizing criteria in the GDM text.

(7) SPL to provide guidance on the need for emergency gates.

(8) SPL to provide guidance on the need for riprap on the downstream channel invert.

(9) NPP to provide recommendations for architectural treatment of the outlet works.

RESULTS

1-11 All required actions resulting from the on-board review meeting have been completed. The results are included in this GDM.

Feature Design Memorandum and Construction Schedule

1-12 Previous to the July 1987 in-progress review meeting, work on the feature design memorandum was scheduled for 1989, with construction beginning in 1991. At the IPR meeting, work on the feature design memorandum was proposed for 1993 and construction of the outlet works would begin in 1996.

II. PROPOSED OUTLET WORKS

Scope

2-01 This section describes the major features that make up the outlet works. A plan showing the outlet works is shown on plate 1. The profile is shown on plate 2. The major features consist of the approach channel, regulating outlet (RO), stilling basin, and downstream channel.

Approach Channel

2-02 A flat approach channel will extend approximately 350 feet upstream of the RO. The invert will be at elevation (El.) 465, 5 feet below the RO intake invert. A 100-foot-wide channel, with the invert at El. 470, will connect the new approach channel with the existing low pool. The upstream end of the approach channel will slope to match the existing ground. Concrete wing walls, approximately 175 feet long, will be located on each side of the approach channel adjacent to the RO. Height of those walls will vary from 5 feet on the upstream ends to 50 feet on the downstream ends. A cross section of the approach channel is shown on plate 2.

Regulating Outlet Structure

GENERAL

2-03 The RO structure will consist of two independent intake structures. Each structure will mirror image the other except the left structure (looking downstream) will include the access tower. The overall dimension at the foundation will be 70 feet by 90 feet. At El. 470 each intake structure will contain a trash structure, three intake passages with upstream bulkhead slots embedded in the piers and a slide gate in each passage, and a low flow channel with upstream trashracks and control by gate valves. The RO structure is shown on plates 3, 4, and 5.

GATE ROOM

2-04 The gate room will be located at El. 500. The floor will be 25 feet by 120 feet. Ceiling height will be 30 feet.

MAINTENANCE DECK

2-05 The maintenance deck will be located at El. 520. From this deck the maintenance bulkhead may be placed in the upstream slots of the intake passage piers and the trash structure may be cleaned. Access to the low flow bypass trashracks for cleaning or removal will be from the maintenance deck. If the low flow bypass gate valves must be removed, a maintenance bulkhead can be placed in the trashrack slots.

ELEVATOR DECK

2-06 Access to the elevator will be from the elevator deck at El. 572. The deck will be four flights of stairs (24 feet) from the control room and access bridge.

MECHANICAL DECK

2-07 Elevator equipment will be located in the center of the tower on the mechanical deck at El. 588. Access will be by stair-way only.

CONTROL ROOM

2-08 The control room will be located at El. 596, at the same level as the access bridge. The control room will contain remote slide gate controls, a toilet, a diesel generator, major electrical equipment, and the stairway to the lower levels.

Regulating Outlet Transition

2-09 The RO transition will transform the six intake passages and two low flow bypass passages into two RO conduits. The width varies from 140 to 53 feet. Total length is 200 feet.

Regulating Outlet Conduits

2-10 Each of the two rectangular RO conduits will be 19 feet by 22 feet. The length of each will be 610 feet.

Stilling Basin

2-11 The stilling basin will consist of a concrete U-Section with a center splitter wall and a runout channel. The concrete portion of the stilling basin will be 260 feet long. The runout channel will be 345 feet long and lined with riprap only along the sides. Total length

of basin and channel will be 605 feet. The concrete portion of the stilling basin is shown on plate 11. Stoplog slots will be provided at the downstream end of the stilling basin for maintenance and inspection stoplogs. Stoplogs could be fabricated during the initial project construction or at a later date.

Architectural Treatment

2-12 A number of factors were considered to determine the type and extent of architectural treatment on the intake tower. The existing control tower has a number of architectural elements including windows, a fluted frieze, and sculpted pier tops. Its rectangular box set on tall piers is a distinct form. Consideration was given to how closely the new intake tower should imitate the original structure. The physical relationship between the two structures is an important factor. Given their distance apart and the distance from which either can be viewed by the public, the need for a strong visual connection is minimized. The cylindrical shape of the new tower is both functionally and structurally appropriate. Windows should be included since the tower will be occupied 24 hours per day druing flood events. The windows need to provide fresh air and also be bullet proof to protect against vandals. To this end, the new intake tower will use a fluted or grooved parapet and bridge railings. These elements will be similar in appearance to the fluted frieze on the control building. Interior materials will be chosen for their durability and ease of maintenance.

Access Bridge

2-13 The access bridge will be a single lane two-span structure. The bridge will connect the intake tower to the dam crest access road at El. 594.4.

Landscape Restoration

2-14 Landscape considerations and restorations will be addressed in the FDM.

III. HYDRAULIC DESIGN

General

3-01 The hydraulic design included herein is for required project releases routed through the regulating outlet works. The hydraulic design of this project conforms to the usual procedures for structures of this type, as outlined in Engineering Manuals, Hydraulic Design Criteria, and based on the results of model and prototype studies. A study was performed to analyze four conceptual designs (see paragraph 1.1). It was determined that two intake structures and tunnels will be required to provide the maximum required discharge of 30,000 cubic feet per second (cfs) (see Prado Dam Operation Schedule for All-River Plan, table 3-1). Each intake structure was analyzed with two and three passages. The three-passage plan was selected to limit vortex formation and economics of gate size. Several tunnel sizes and shapes were analyzed for the selected alignment. The final dimensions were based on the best hydraulic section that minimized structural requirements (see plates 3 and 4). Three stilling basins were analyzed: a dual basin, single basin, and single basin with a splitter wall. The latter was selected as the recommended alternative. Two main alignments were analyzed for the downstream channel. A backwater was computed for each alignment using HEC-2 for various widths, depths, and bend radii. The selected alignment is shown on plate 1. It has been determined that all hydraulic features of this project can be adequately designed for proper operation without model studies.

Table 3-1. Prado Dam Operation Schedule for All-River Plan.

Elevation (Feet)	Net Storage (Acre Feet)	Minimum Outflow (cfs)	Nominal Outflow (cfs)	Maximum Outflow (cfs)	Spillway (cfs)
470 (Gate Sill)	0	0	0	0	0
490	-	-	-	1,500	0
500	4,000	50	200	2,000	0
501	6,000	50	300	4,000	0
510	18,100	100	2,000	8,000	0
520	42,200	100	12,000	15,000	0
530	76,500	200	20,000	25,000	0
540	123,000	200	30,000	30,000	0
550	183,900	300	30,000	30,000	0
560	263,500	300	30,000	30,000	0
563 (Spillway Crest)	292,026	300	30,000	30,000	0
565	313,044	0	20,870	20,870	9,130
568	346,263	0	0	0	38,300
570	369,622	0	0	0	65,650
580	500,607	0	0	0	279,700
590	659,600	0	0	0	587,600
594.4 (Top of Dam)	725,000	0	0	0	720,000

RO Trash Structure

GENERAL

3-02 The trash structure is designed to provide minimum resistance to flow, and to pass all material except that which would make the outlet inoperative. The trash structure consists of upright concrete beams and horizontal struts. The vertical and horizontal clear openings are 6.5 and 9 feet, respectively. The top of the trash structure, El. 516 feet, is 46 feet above the sill invert, El. 470 feet, and the total width of the trash structure is 140 feet (see plates 3 and 4). The total net area is 3,300 square feet. An average velocity of 9.1 feet per second (fps) will occur through the trash struts with a maximum discharge of 30,000 cfs. Guidance from EM 1110-2-1602 recommends that velocities through the trashrack not exceed 15 fps.

TRASH STRUT ENERGY LOSSES

3-03 Equation 2-12, EM 1110-2-1602, was used to determine energy losses through trash struts. A loss coefficient K value of 0.02, recommended in paragraph 3-5.a, EM-1110-2-1602, was used for velocity computations. Trash struts were assumed 50 percent clogged for capacity design computations. For this condition a loss coefficient K value of 0.28 was calculated using equation 11, page 366, "Design of Small Dams," Bureau of Reclamation. These loss coefficients are referenced to average velocity heads in intake conduits proper, just upstream of gates.

RO Intake

GEOMETRY

3-05 Entrance invert will be at El. 470 feet. Six intake passages, each 9.75 feet wide by 14.75 feet high, will be used. Six passages are necessary to keep hydraulic loading on gates within acceptable limits while minimizing number of passages. Vortex formation controls the intake passage size. Intake passages are larger in area than required to pass design flows so that vortices will not form for pool elevations between El. 525 and El. 540. Allowable discharge versus pool elevation, based on vortex formation, is shown on figure 3-1. Vortex computations are based on information given in EM 1110-2-1602, plate C-35. Elliptical curves provided on intake passage roof and sides will transition the entrance from a 16.25-foot-wide by 19.67-foot-high opening to a 9.75-foot-wide by 14.75-foot-high passage. The elliptical entrance curves, shown on plate 4, are based on Technical Memorandum No. 2-428, Report No. 2, "Investigation of Entrances Flared in Three Directions and in One Direction," Waterways Experiment Station. The pressure conditions will be positive along the length of the intake curves upstream of gates to prevent cavitation for the range of design discharges. The maximum pressure drop of approximately 22 feet will occur for an operating head of 70 feet over the invert sill at a discharge of 5,000 cfs per conduit.

PRADO

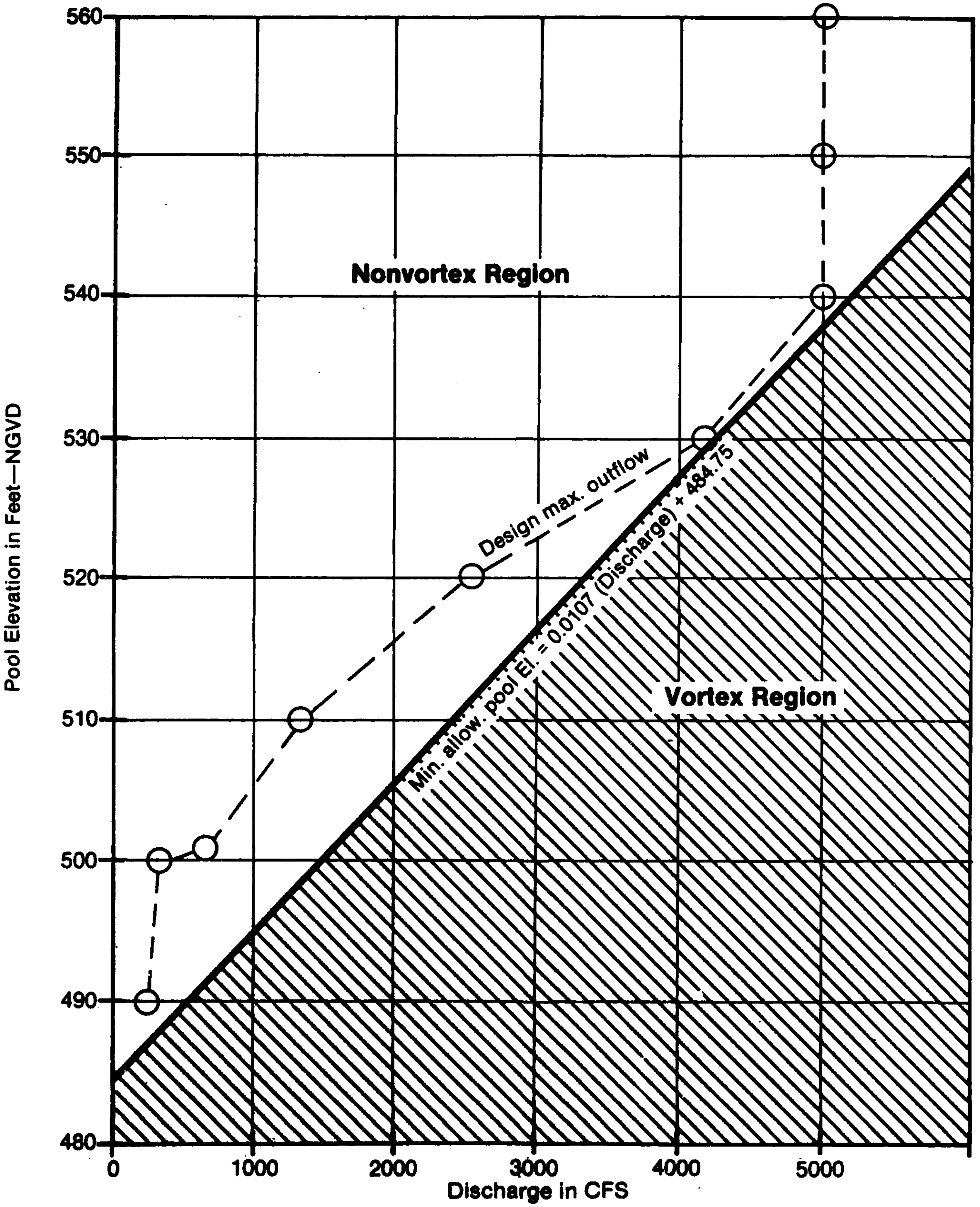


Figure 3–1 Allowable discharge for one intake operating based on vortex formation.

ENERGY LOSSES

3-06 An intake loss coefficient K value of 0.16 was used for capacity design and a value of 0.10 was used for velocity design, as recommended in paragraph 3-7, EM 1110-2-1602. A K value of 0.01 was used for gate slot losses, as recommended in above reference. A Manning's "n" value of 0.015 was used for capacity design and an "n" value of 0.008 was used for velocity design. The value selected for velocity design is based on a recommendation in paragraph 2.12.g, EM 1110-2-1602, which states that the smooth pipe curve should be used for computing conduit flow velocity for design of outlet works energy dissipators and estimates for critical low pressures. Equivalent f values were calculated for given values of Manning's coefficient of roughness. Frictional loss coefficient K values through the intake passages of 0.07 and 0.02 for capacity and velocity design, respectively, were computed based on the Darcy-Weisbach equation.

RO Slide Gate Rating

3-07 The regulating outlet rating curves for various gate openings are shown on figure 3-2. Average values of energy loss coefficients have been used to approximate actual operating conditions. A loss coefficient K value of 0.10 was calculated for trash struts using equation 11, page 366, "Design of Small Dams," Bureau of Reclamation, assuming 25 percent clogging of struts. An intake entrance loss coefficient K value of 0.13 was used and is the mean value of the range recommended in paragraph 3-7, EM 1110-2-1602. The frictional loss coefficient K value of 0.045 was calculated based on the Darcy-Weisbach equation using an equivalent Manning's coefficient of roughness equal to 0.012. All loss coefficients are referenced to velocity head in intake passages just upstream of gates. Values of loss coefficients used for capacity, rating curves, and velocity design are summarized in table 3-2.

PRADO

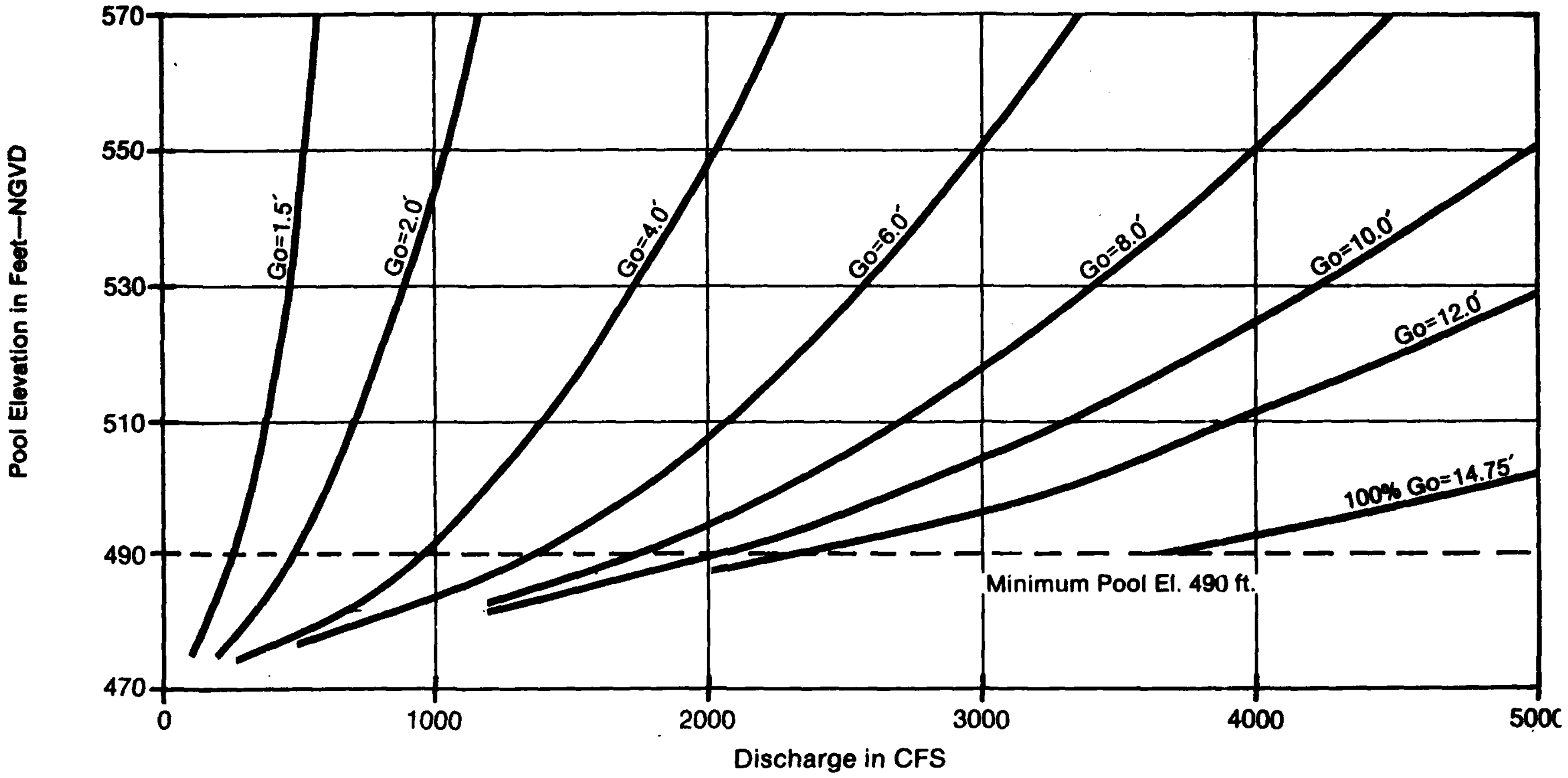


Figure 3–2 Rating cuves for single main operating gate.

Table 3-2. Energy Loss Coefficients (K Values).

	Capacity	Rating	Velocity
TRASH STRUTS	0.28 (1)	0.10 (2)	0.02 (3)
INTAKE ENTRANCE	0.16 (4)	0.13 (5)	0.10 (6)
FRICTION, INTAKE PASSAGEWAY	0.07 (7)	0.045 (8)	0.02 (9)
GATE SLOT	0.01 (10)	0.01	0.01
TOTAL	0.52	0.285	0.15

Note: All loss coefficients are referenced to conduit proper upstream of gates.

(1) "Design of Small Dams," Bureau of Reclamation, page 366, eq. 11, trash struts 50 percent clogged.

(2) Same reference as for (1), trash struts 25 percent clogged.

(3) "EM 1110-2-1602," paragraph 3-5a., page 3-3.

(4) "EM 1110-2-1602," paragraph 3-7, page 3-5.

(5) Mean of range given in reference (4).

(6) Same as reference (4).

(7) Darcy-Weisbach equation - equivalent f, given Manning's roughness coefficient $n = 0.015$.

(8) Same as for (7) except $n = 0.012$.

(9) Same as for (7) except $n = 0.008$.

(10) "EM 1110-2-1602," paragraph 3-7, page 3-5.

LOW FLOW TRASHRACK

3-08 The trashrack is designed to provide minimum resistance to flow and to pass all material except that which would make the outlet inoperative. The trashrack consists of 3/4-inch-wide bars with vertical and horizontal spacings of 1.25 feet. The top of the trash structure, El. 480, is 10 feet above the sill invert, El. 470, and the total width of each low flow trashrack is 5 feet (see plate 4). The total net area is 46 square feet. An average velocity of 10.9 fps will occur through the trash bars with a maximum discharge of 500 cfs. Guidance from EM 1110-2-1602 recommends that velocities through the trashrack not exceed 15 fps. Equation 2-12, EM 1110-2-1602, was used to determine energy losses through trash bars. A loss coefficient K value of 0.027 calculated using equation 11, page 366, "Design of Small Dams," Bureau of Reclamation, was used for gate rating computations.

LOW FLOW BYPASS

3-09 The two low flow bypasses shown on plate 3 will elimimate the need to operate regulating outlet slide gates at openings of less than 6 inches. Flow will be controlled with 2.0-foot-wide by 3.5-foot-high vertical slide gates. Gates will be located at Station 10+00 in line with the main regulating outlet control gates. Provisions have been made for maintenance bulkheading. The entrance invert will be at El. 470. The low flow bypass rating curve and minimum flow criteria are shown on figure 3-3. This figure includes: (1) minimum required flow conditions for Prado Dam operation; (2) discharge rating curves for a single 9.75-foot-wide by 14.75-foot-high main regulating outlet gate with minimum opening (6 inches); and (3) discharge rating curves for one regulating outlet low flow bypass line. The design flows are discharges less than those which can be controlled when a single regulating gate is open 6 inches. Note that the system is designed so that one bypass is sufficient to pass minimum flows. This design provides the flexibility to pass desired low flows while one bypass or tunnel is closed for maintenance or other reasons. Elliptical curves, where the minor axis is equal to one-third the major axis, are provided on intake passage roof and sides for the low flow bypass lines. The entrances will transition from 3.33-foot-wide by 4.67-foot-high openings to 2.0-foot-wide by 3.5-foot-high intake conduits. Four feet downstream of the gates the section height increases to 4.5 feet by expansion of the roof. The conduits then transition to narrow 14-inch-wide by 70-inch-high passages, and intersect the outlet conduit wall at approximately Station 11+65 with an angle of 20 degrees. This design minimizes the opening in the main conduit. At gate openings over 2.75 feet the low flow bypass conduits may flow full. Possible slug flow and reduction in capacity due to air-entrainment (bulking) should be investigated at the FDM level.

PRADO

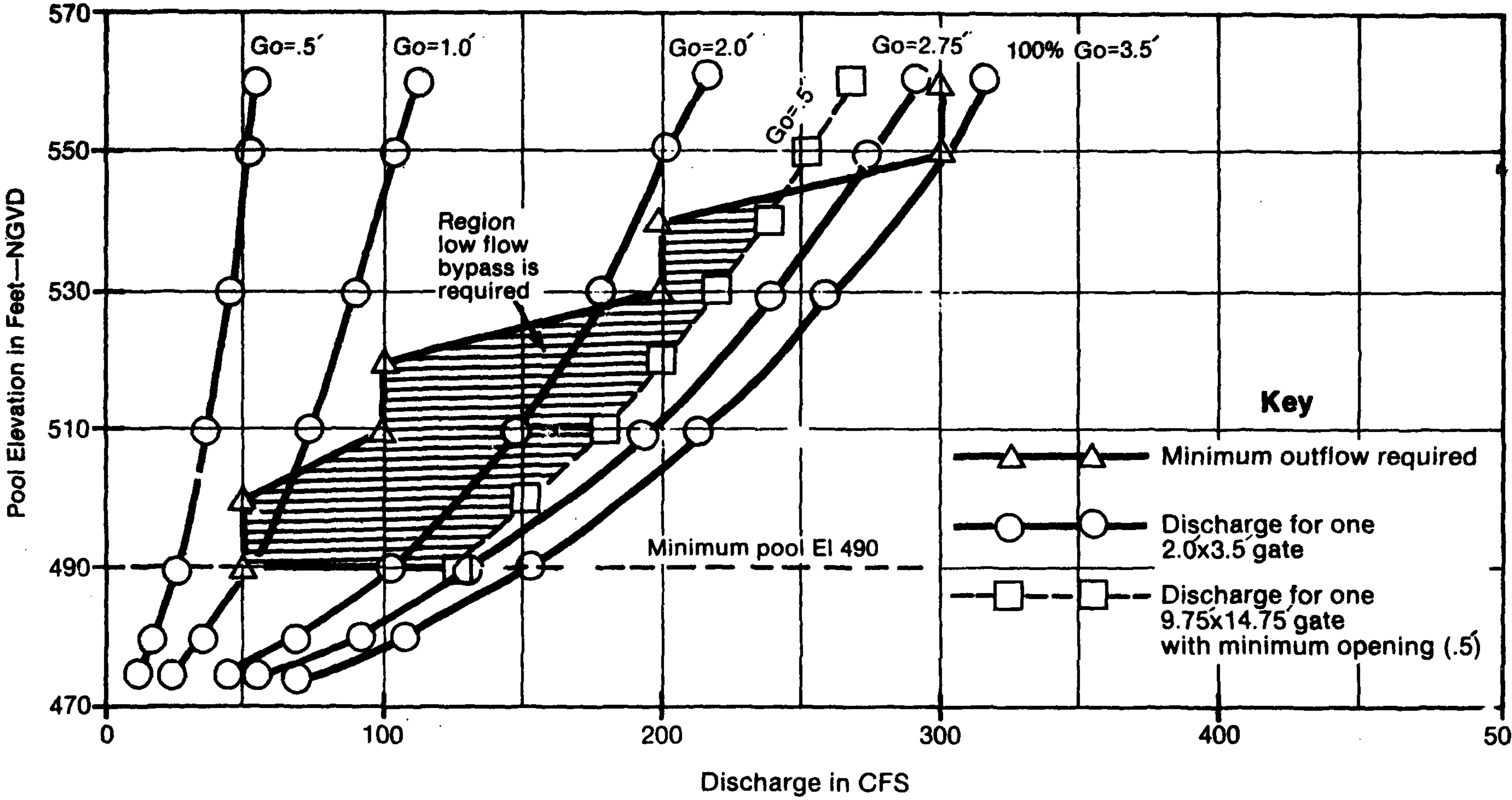


Figure 3–3 Low flow bypass rating curves and minimum flow criteria.

Air Demand

REGULATING OUTLET

3-10 The air demand downstream of each operating gate is based on the procedure outlined in EM 1110-2-1602. The maximum water velocity, based on smooth pipe coefficients in the conduit, is 72 fps and occurs at the vena contracta. This design was based on a pool elevation of 563 feet and a total regulating outlet discharge of 30,000 cfs. The above conditions give the maximum air-demand-to-discharge ratio of 1.13. This results in an air requirement of 650 cfs per intake conduit which, if limited to a maximum velocity of 150 fps, requires an air vent with a minimum area of 4.33 square feet in each of the six intake conduits. Two 22-inch-diameter vents with a plenum, located on the roof immediately downstream of the regulating outlet gate as shown in plates 4 and 5, will be used in each conduit to ensure even air distribution. In the main tower two main vents, each 52 inches in diameter, will be provided to supply air to both sides of the intake structures.

LOW FLOW BYPASS

3-11 The air demand downstream of each low flow bypass gate is based on procedures described in the above paragraph. The maximum air requirement is estimated to be 80 cfs. Air velocity has been limited to 100 fps since it is expected that low flow bypass design flow will occur more frequently and for longer durations than the main regulating outlet design flow. This assumption should be investigated in more detail at FDM level. A 12-inch-diameter vent with a 5-inch by 24-inch plenum will distribute air in each low flow bypass line.

RO Transition

3-12 The regulating outlet transition for each of the intake structures converges flow from three 9.75-foot-wide by 14.75-foot-high conduits into one 19-foot-wide by 23-foot-high rectangular conduit (see plate 3). The width of the inner wall separating the two main regulating outlet conduits is fixed at 5 feet due to structural and economic considerations. The offset distance along the outer wall between the vertical slide gates and the main conduit is 33.75 feet. General design guidance in EM 1110-2-1602 recommends a ratio of offset distance to transition length of .123 ft/ft for the design conditions at Prado. This gives a transition length of 275 feet. The ratio of offset distance to length is .172 ft/ft for the existing Prado outlet works. The length for the proposed design was shortened to 196 feet by using the existing outlet works ratio and by designing the piers and walls of the transition with reverse curves formed by two circular arcs. The existing transition has functioned satisfactorily for 47 years and was designed for a maximum head of 90.0 feet, while the proposed maximum operating head is 93.0 feet. The difference in design heads is considered insignificant. Therefore, a transition design based on the existing project offset distance-to-length ratio should function

satisfactorily for the proposed project. Any additional decrease in transition length will increase the chance of cavitation damage and may cause poor hydraulic flow conditions in the main regulating outlet conduits. The reverse curve for the innermost wall produces an offset distance of 7.5 feet which occurs over a length of 140 feet, giving an offset distance-to-length ratio of .054 ft/ft. The inner pier and outer pier extend for a distance of 105 and 120 feet, respectively, downstream from the gates. This configuration prevents a constriction of flow from the outermost conduit. The minimum pier thickness is 2.0 feet. Using Corps program HEC-2 and a Manning's "n" value of 0.012, an energy loss of 12 percent was calculated through the transition. An energy loss of 0 percent was used for design of the downstream energy dissipator (maximum velocity) and an energy loss of 20 percent was used for conduit capacity design (maximum depth). These computations, from the regulating outlet gates downstream to the end of the transition, are summarized in table 3-3. Values are expected to cover the range of possible extremes.

RO Conduit

3-13 Various tunnel shapes and sizes were analyzed. Based on structural and economic considerations, a cut and cover conduit option was selected. The two rectangular conduits, each 19 feet wide by 23 feet high, will pass a maximum required discharge of 15,000 cfs each with open channel flow. Two flow conditions were examined: (1) maximum velocity, for design of the stilling basin; and (2) maximum depth, for design of system capacity. Depths at the upstream end of the tunnel were determined on the basis of maximum and minimum energy losses through the transition (see paragraph 3.7). These depths were then used in the CORPS H6209 program to calculate water surface profiles through the conduits. Manning's "n" values of 0.008 and 0.015 were used for velocity and capacity design, respectively. The maximum depth in the conduit was found to be 18.7 feet at the portal exit. This is 81 percent of the 23-foot conduit height, which leaves the upper 19 percent of the conduit open to ensure open-channel flow. Numerical results for analysis of the two cases are listed in table 3-4, and a sketch of the water surface profiles is shown in figure 3-4. The maximum ratio of air to water will be 0.13 (see paragraph 3.6). Some of this air will be induced to flow along the water surface due to the shear field created by relative movement of air and water ("Air-Water Flow in Hydraulic Structures," EM No. 41, Bureau of Reclamation, page 44). Using plate 45 in EM 1110-2-1601, the increase in depth due to air-entrainment was computed to be an average of 12 percent between transition and portal exit. Design information on this plate was derived for wide chutes, however, with width greater than five times the depth. Data for flows through narrow chutes show marked effects of sidewalls on the amount of air entrained (HDC sheet 050-3). A reasonable estimate for bulking in the conduit at Prado is probably 5 to 10 percent. Assuming that all air from air vents is entrained in flow, the maximum depth (air-water mixture) in the conduit will be 21.1 feet. This will leave a minimum of 1.9 feet of freeboard in the conduit.

Table 3-3. Velocity and Capacity Design Computations Downstream from Regulating Outlet Gates to End of Transition.

Variable	Maximum Velocity	Maximum Depth
Maximum discharge (total)	30,000 cfs	30,000 cfs
Pool elevation	563 ft	540 ft
Gate opening	9.1 ft	11.2 ft
Depth at Vena Contracta	7.0 ft	8.9 ft
Velocity at Vena Contracta	73.3 ft/s	57.5 ft/s
Specific energy at Vena Contracta	90.3 ft	60.3 ft
Percent energy loss through transition	0%	20 %
Specific energy at end of transition	90.3 ft	48.2 ft
Depth at end of transition	11.1 ft	17.9 ft
Velocity at end of transition	71.5 ft/s 3	44.1 ft/s

Table 3-4. Velocity and Capacity Design Computations Downstream from End of Transition to Portal Exit.

Variable	Maximum Velocity		Maximum Depth	
Maximum discharge (both conduits operating)	30,000	cfs	30,000	cfs
Pool elevation	563	ft	540	ft
Depth at end of transition	11.1	ft	17.9	ft
Velocity at end of transition	71.5	ft/s	44.1	ft/s
N-Value through conduit	0.008		0.015	
Velocity at end of conduit	70.6	ft/s	42.2	ft/s
Depth at end of conduit	11.2	ft	18.7	ft
Percent of conduit height	48.7	%	81.3	%

PRADO OUTLET WORKS

Watersurface Profile

Q = 15,000 CFS

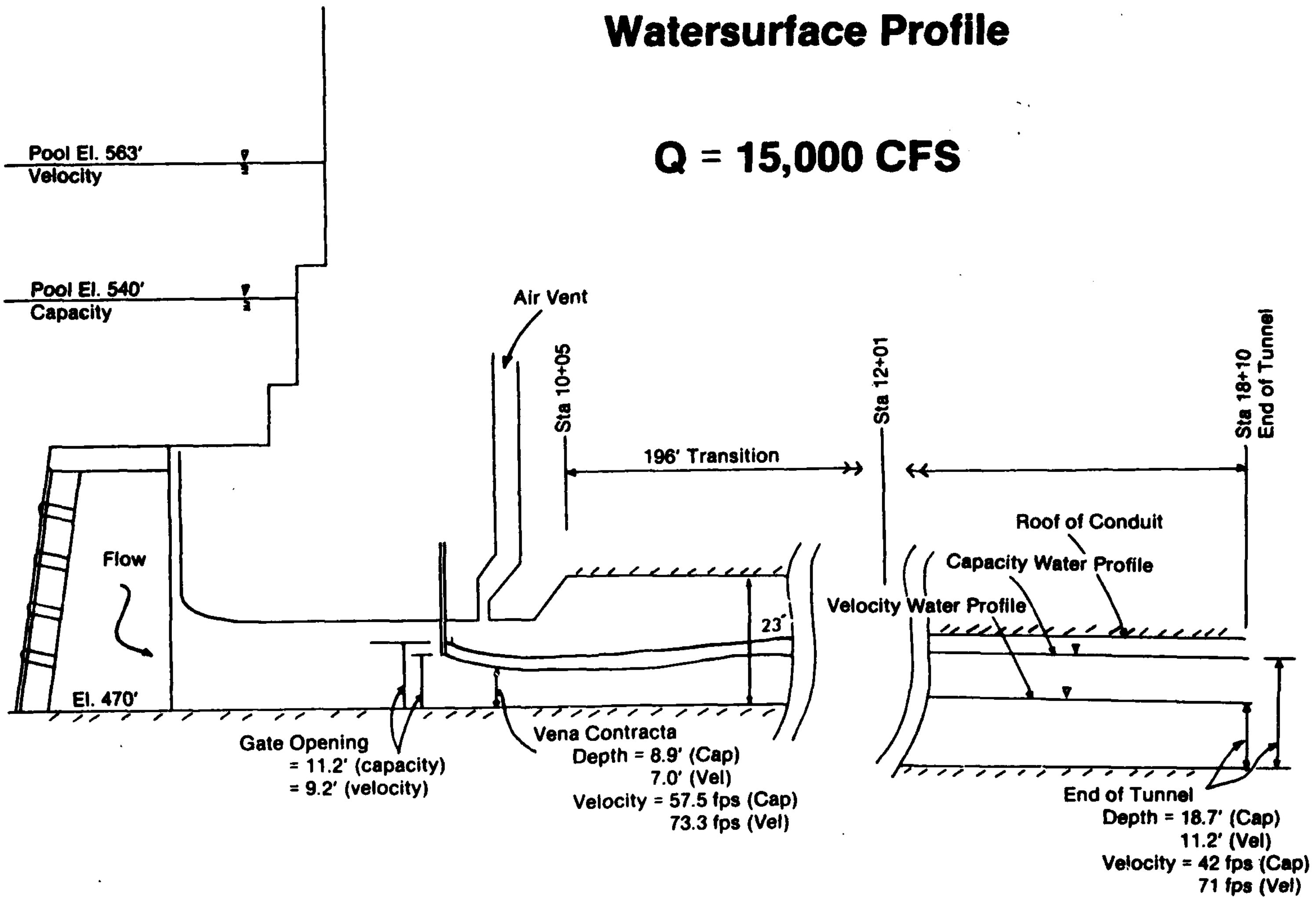


Figure 3–4 Flow profile for capacity and velocity.

Stilling Basin

3-14 The stilling basin shown on plate 7 is designed for the maximum discharge of 30,000 cfs, in accordance with EM 1110-2-1602. The 5-foot-wide splitter pier divides the basin, providing energy dissipation for releases up to 15,000 cfs through either regulating outlet. Outlets may be operated together or independently. When one outlet is operated independently, flow conditions in the channel downstream of the basin may cause scour and erosion. This possibility should be investigated at the FDM level. The maximum velocity of the jet leaving the conduit is 70.6 ft/s, using minimum energy losses through the system. The exit chute transition leading from the outlet portal to the basin floor is formed by a parabolic curve. The outerside walls of the chute transition diverge at a ratio of 1:7. Each basin is 36 feet wide and 133.5 feet long. Two rows of 5-foot-wide by 5-foot-high baffle blocks are located 70 feet and 95 feet below the upstream end of the basin. With only one regulating outlet operating at a discharge of 15,000 cfs, the D2 (provided)/D2 (required) ratio is 0.85. With both outlets operating at a discharge of 15,000 cfs, for a total discharge of 30,000 cfs, the D2 (provided)/D2 (required) ratio is 0.92. The top of the stilling basin walls is at El. 473.0, which provides 3 feet of freeboard above the maximum tailwater depth condition (see paragraph 3.11). The length/D2 (required) ratio is 2.95. As recommended in EM 1602, the tailwater depth at low discharges was checked to assure that the hydraulic jump occurring on the parabolic chute would be downstream of the point at which the slope is 1V on 6H.

Stilling Basin Runout Channel

3-15 The stilling basin runout channel is riprap lined, as recommended in EM-1110-2-1602. The runout channel has a bottom slope of 1V on 8.9H. This is steeper than a slope of 1V on 10H which is commonly used, thus shortening the length of the runout channel. This length leaves an adequate distance to make the required bends in the downstream outlet channel. Over a length of 357 feet, the bottom of the runout channel flares from 86.6 feet wide at the stilling basin exit to 140 feet wide at the start of the downstream channel.

Downstream Channel

3-16 The layout of the downstream outlet channel is shown on plates C-1, C-2, and C-8. The channel is designed to pass the maximum outlet works release of 30,000 cfs. The location of the upstream end of the channel was determined by the alignment of the regulating outlet and the length of the stilling basin. At the downstream end of the channel there are constraints resulting from the location of the existing State Highway No. 71 bridge, located 1,400 feet below the existing regulating outlet. Two bridge piers, spaced 110 feet apart, are located in the channel approximately 80 feet in from each bank. To provide proper flow alignment with the piers, the new channel will be merged into the

existing channel approximately 200 feet upstream of the highway bridge. The skew angle of the bridge piers to the flow lines will be approximately 3 to 4 degrees. Due to the alignment of the new regulating outlet works and the existing state highway bridge, it is necessary to provide two bends in the outlet channel. The centerline radius of the downstream bend is 582 feet, and of the upstream bend, 800 feet. The left and right sides of both the upstream and downstream bends are simple circular arcs drawn from individual radius points. The channel bottom width increases from 140 feet to 200 feet through the upstream bend and from 200 feet to 265 feet through the downstream bend. The side slopes of the trapezoidal cross section are approximately 1V on 2H through the entire length of the channel, until it transitions into the existing channel which has side slopes of approximately 1V on 3H. Stepbackwater computations were run from the drop structure downstream of the existing highway bridge, back to the new stilling basin, using the Corps HEC-2 backwater program. The computations were done using the elevations of the original invert of the existing outlet channel rather than the surface of the material that has been deposited in the channel. It is recommended that the 1 to 3 feet of sediment that has been deposited in the existing channel be removed between the drop structure and the proposed outlet channel. Losses at the bridge due to debris caught on the piers were assumed to be zero. It is assumed that the channel will be maintained, which will eliminate the source of debris between the regulating outlet and the bridge. Maximum and minimum "n" values were selected for the proposed riprap channel using U.S. Geological Survey (USGS) Paper 1849, "Roughness Characteristics of Natural Channels," Chow's "Open-Channel Hydraulics," and EM-1110-2-1601. Two separate water surface profiles were run from the existing drop structure up to the exit of the stilling basin. The minimum tailwater condition was run with "n" values of 0.025 in the existing channel and 0.027 in the proposed channel, with no correction for bend losses. This gave water surface elevations of 467.6 and 463.1 feet at the downstream end of the stilling basin for discharges of 30,000 cfs and 15,000 cfs, respectively. These tailwater elevations were used to design the stilling basin. The maximum tailwater condition was run with "n" values of 0.027 in the existing channel and 0.032 in the proposed channel, respectively, and corrections were made for bend losses and for expansion-contraction losses through the runout channel. For a discharge of 30,000 cfs, this set of conditions gave a water surface elevation of 470.0 feet, which is the tailwater elevation used in the design of the top elevation of the stilling basin walls. Results of the maximum backwater profile for a discharge of 30,000 cfs are given in table 3-5 and shown on figures 3-5 and 3-6. Trapezoidal channels with bottom widths less than 140 feet at the upstream end were analyzed. Increased flow velocities made the required stone size for erosion protection significantly larger, however. A low flow channel should be considered for final design.

Table 3-5. Backwater Profile Computations.

Variable	Minimum Tailwater Condition	Maximum Tailwater Condition
W.S. El. at drop structure	458.9 ft	3458.9 ft
Manning's "n" value in existing channel	0.025	0.027
Headloss due to bends in existing channel	0.0 ft	0.6 ft
W.S. El. at U/S end of existing channel	463.5 ft	464.4 ft
Manning's "n" Value in proposed channel	0.027	0.032
Headloss due to bends in proposed channel	0.0 ft	1.2 ft
W.S. El. at stilling basin exit	470.0 ft	3470.0 ft
Minimum velocity in proposed channel (@ Sta. 36+45, halfway thru D/S bend)	----	7.9 ft/s
Maximum velocity in proposed channel (@ Sta. 25+43, U/S end of channel)	14.8 ft/s	----
Average velocity in D/S bend	9.7 ft/s	8.7 ft/s
Average velocity in U/S bend	13.2 ft/s	10.8 ft/s

PRADO

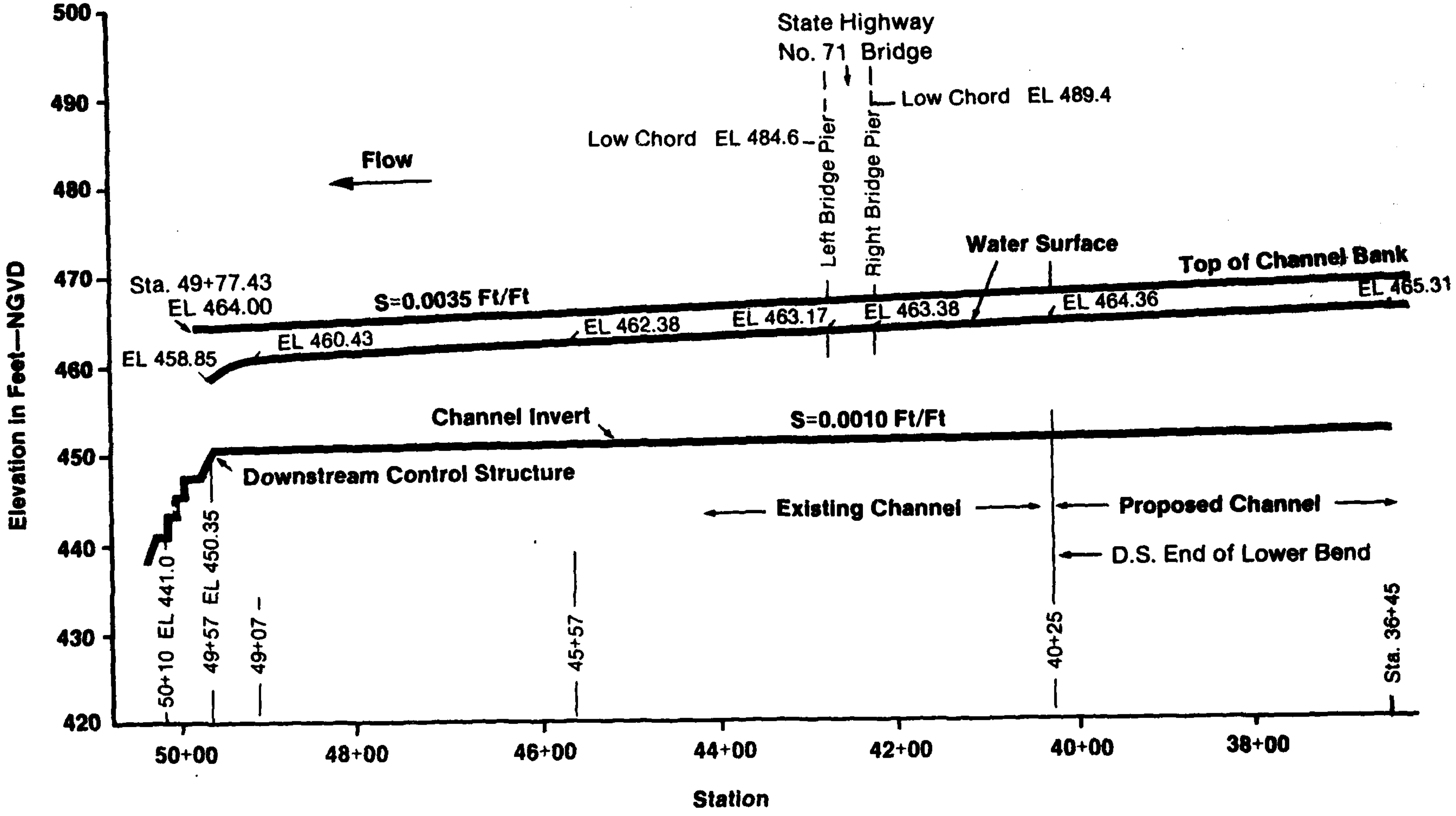


Figure 3–5 Maximum Water Surface Profile in Downstream Channel for Discharge of 30,000 cfs- from Downstream Control to Sta. 36+45.

PRADO

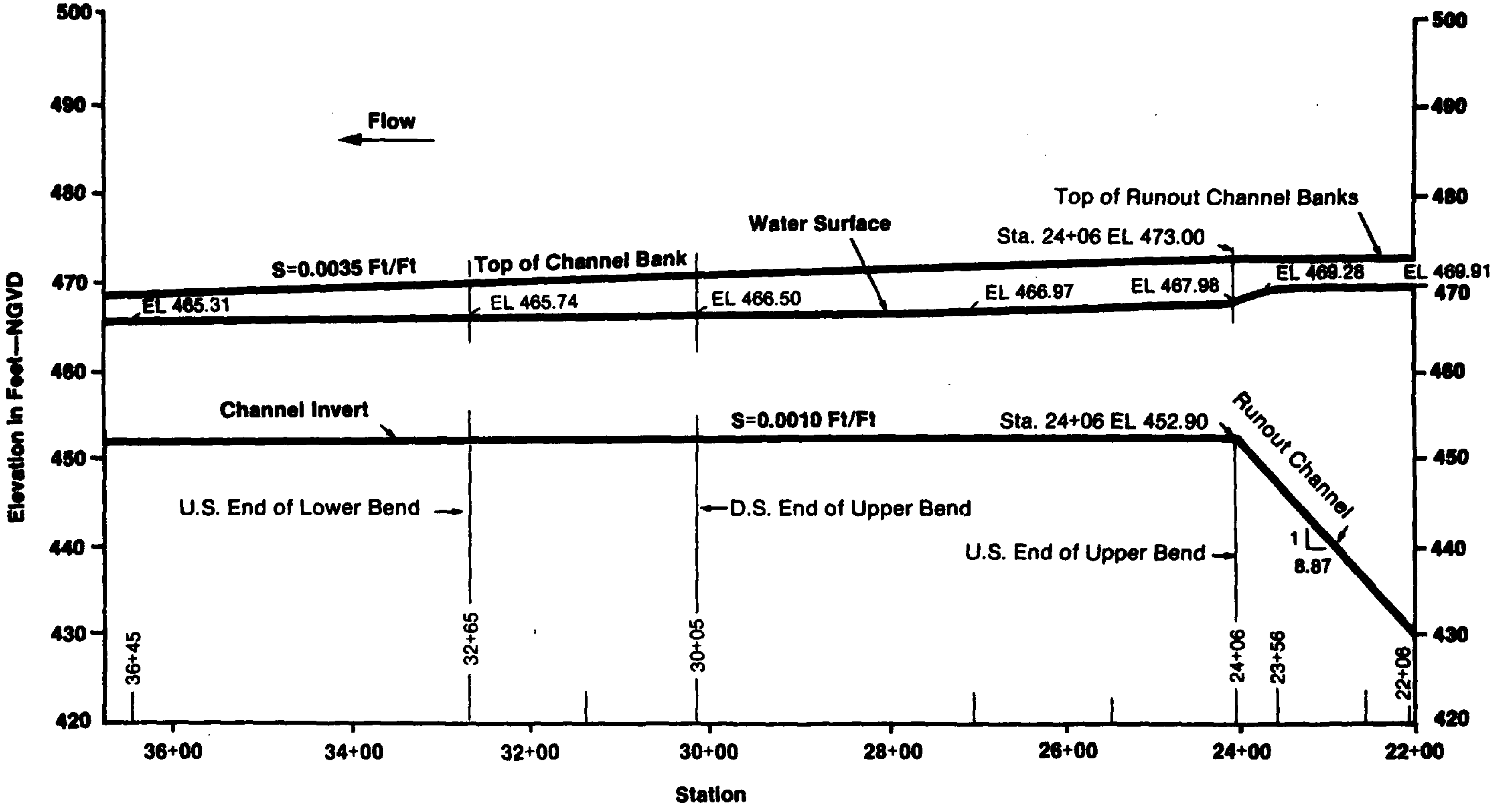


Figure 3-6 Maximum Water Surface Profile in Downstream Channel for Discharge of 30,000 cfs- from Sta. 36+45 to Stilling Basin Runout Channel

IV. STRUCTURAL DESIGN

General

4-01 This section presents the basic data, design criteria, and methods that will be used in design of the regulating outlet (RO) and stilling basin.

Design Criteria

4-02 Design will be based on accepted engineering practice and will conform to the following Engineering Manuals (EM's), Engineering Technical Letters (ETL's), and Engineering Regulations (ER's):

EM 1110-1-2101	Working Stresses for Structural Design
EM 1110-2-2000	Standard Practice for Concrete
EM 1110-2-2102	Waterstops
EM 1110-2-2103	Details of Reinforcement - Hydraulic Structures
EM 1110-2-2400	Structural Design of Spillways and Outlet Works
EM 1110-2-2502	Retaining Walls
EM 1110-2-2902	Conduits, Culverts, and Pipes
ER 1110-2-1806	Earthquake Design and Analysis for Corps of Engineers Projects
ETL 1110-2-256	Sliding Stability
ETL 1110-2-265	Strength Design Criteria for Reinforced Hydraulic Structures

Other applicable ETL's, EM's (EM 1110-series), draft EM's, and codes listed therein.

Material Properties

CONCRETE

4-03 Concrete design strengths will be based on 28-day compressive strengths of 3,000 and 4,000 psi. Design will be in accordance with EM 1110-2-2000. The RO, stilling basin, and all other concrete structures except the wing walls will be designed using 4,000 psi concrete. Wing walls will be designed using 3,000 psi concrete. ASTM A615 grade 60 reinforcing steel will be used where concrete is reinforced. Design yield strength will be 48,000 psi, in accordance with ETL 1110-2-265. Details of reinforcement will be in accordance with EM 1110-2-2103.

STRUCTURAL STEEL

4-04 Structural steel will be A36 carbon steel or A304 CRES. The A36 steel will be painted or galvanized. Allowable steel stresses will be based on EM 1110-2-2101.

ROCK

4-05 The RO and stilling basin foundations will be built on bedrock. Siltstone and sandstone are the primary rock types which are expected to be found at the site. Design values are as follows:

Rock Property	Bedrock
Friction angle (phi)	19°
Cohesion value (c)	1,000 psf
Bearing Capacity	2.5 tons/ft^2

BACKFILL AND ROCK LOADS

4-06 Lateral and gravity loads from backfill and rock where concrete is cast against rock have the following unit weights, friction angles, and at-rest coefficients:

	Moist (pcf)	Saturated (pcf)	Angle (Phi)	At-Rest Coefficient (Kr)
Backfill	115	130	34x	0.44
Rock	115	130	19x	0.50

SEISMIC

4-07 The peak ground accelerations at the Prado Dam site follow:

Maximum Credible Earthquake (MCE)	Operating Basis Earthquake (OBE)
0.6g	0.3g

WATER ELEVATIONS

4-08 The following are pertinent water elevations:

Probable Maximum Flood (PMF)	El. 590
Standard Project Flood (SPF)	El. 567
Spillway Crest	El. 530
Debris Pool (Normal Operating Condition)	El. 490

Design for the RO Structures

GENERAL

4-09 The RO structures will be designed as freestanding independent structures. The major significant difference will be that the left structure (looking downstream) will have an access tower and the right structure will not. Loads and analysis will be made in accordance with the draft EM, "Structural Analysis and Design of Intake Towers."

LOADS

4-10 The following loads will be considered in the design of the regulating outlet structures:

(1) Structure dead load.

(2) Uplift water pressure.

(3) Wind pressure of 30 pounds per square foot (psf).

(4) Seismic load.

(5) Water load.

(6) Soil load (earthfill).

LOADING CONDITIONS

4-11 The RO structures will be designed to resist the following loading conditions:

(1) Loading Condition I, Construction Condition. Only the dead load of concrete and wind load in the direction producing the highest foundation pressure will be considered.

(2) Loading Condition II, Construction Condition with Fill. Dead load from the completed or partially completed structure and earthfill will be considered.

(3) Loading Condition III, Normal Operating Condition. Dead load of the completed structure, earthfill in-place, and pool at the normal operating level. During dry periods when there is no pool, this condition will be the same as Loading Condition II.

(4) Loading Condition IV, Extreme Operating Condition. Structural components (walls, piers, floors, etc.) and the foundation will be checked for the stresses caused by the following conditions:

  (a) Pool at probable maximum flood (PMF) level. All gates shut.

  (b) Pool at standard project flood (SPF) level. All gates on one side of the structure shut, gates on the other side open.

  (c) Pool at SPF level. All but one gate shut.

(5) Loading Condition V, Construction Condition with Earthquake. Earthquake load will be applied without any pool.

(6) Loading Condition VI, Operating Condition with Earthquake. Earthquake load will be applied with earthfill in-place and the pool at the normal operating level.

OVERTURNING STABILITY

4-12 Analysis of the RO structures will be made for all loading conditions. The structure will be investigated using the column formula ($P = \frac{F}{A} \pm \frac{FeC}{I}$) to determine the percentage of the base in compression under the applicable loading conditions. Overturning stability criteria and results from preliminary analysis for the various loading conditions are given in table 4-1.

Table 4-1. Regulating Outlet Tower Overturning Stability Criteria and Results from Preliminary Analysis.

Loading Condition	Minimum Base Areas in Compression (Rock Foundation)	Computed Base Area in Compression Computed	Minimum Bearing Capacity* Factor of Safety Required	Bearing Capacity* Factor of Safety
Construction Condition	50%	100%	2.0	3.0
Construction Condition with Fill	50%	100%	2.0	3.6
Normal Operating Condition	75%	100%	3.0	3.6
Extreme Operating Condition	50%	100%	2.0	9.3
Construction Condition with Earthquake	Resultant Within Base (RWB)	90%	Not Applicable (NA)	NA
Operating Condition with Earthquake	RWB	77%	NA	NA

*Maximum bearing capacity is 7.5 tons/ft^2.

SLIDING STABILITY

4-13 Sliding stability for the RO structures will be analyzed in accordance with ETL 1110-2-256. Loading conditions will be the same as required for overturning stability. Calculations will be made using the sliding stability of concrete structures (CSLIDE) computer program developed by the Waterways Experiment Station (WES) under the Computer Aided Structural Engineering (CASE) Project. The computed sliding stability factors of safety and the minimum required factors of safety are shown in table 4-2. Computations for sliding in the direction of

flow are based on independent movements of the intake structures. To resist sliding in the direction transverse to the flow, the structures will connect at a narrow bearing pad near the base of the structure. Transmitting the sliding force through the structure will allow the soil on the opposite side of the structure to develop passive resistance to any possible sliding.

Table 4-2. Regulating Outlet Tower Sliding Stability Results from Preliminary Analysis.

Loading Condition	Computed Factor of Safety	Minimum Required Factor of Safety
I	10	2.0
II	4.1	2.0
III	4.8	2.0
IV	10	2.0
V	1.7	1.3
VI	1.7	1.3

EARTHQUAKE DESIGN AND ANALYSIS

(1) General. Regulations in ER 1110-2-1806 require seismic design to be considered for new dams and appurtenant structures that retain or have the potential to retain a permanent pool. If a reservoir could be lost due to a failure caused by earthquake loading and the result would cause property damage and/or loss of life, seismic design is required. The draft EM, "Structural Analysis and Design of Intake Towers," states that the pool levels used for the operating conditions should be the ones judged to exist with the selected design earthquake event. Under normal operating conditions, the pool level will be assumed to be no higher than El. 490 during a seismic event.

(2) Stability. The draft EM, "Structural Analysis of Intake Towers," requires a stability analysis by a seismic coefficient method. The seismic coefficient is found in ER 1110-2-1806. Prado Dam is located in Zone 4 as shown on the seismic zone map of California, Nevada, and Arizona. The corresponding seismic coefficient is 0.20. Guidance from OCE indicates that when the peak ground acceleration of the maximum credible earthquake (MCE) exceeds 0.2g, the seismic coefficient should be increased to match one-half of the site-specific peak ground acceleration for the MCE. A seismic coefficient of 0.30 will be used for the RO structure and all appurtenant structures. Results from the preliminary analysis are shown in tables 4-1 and 4-2.

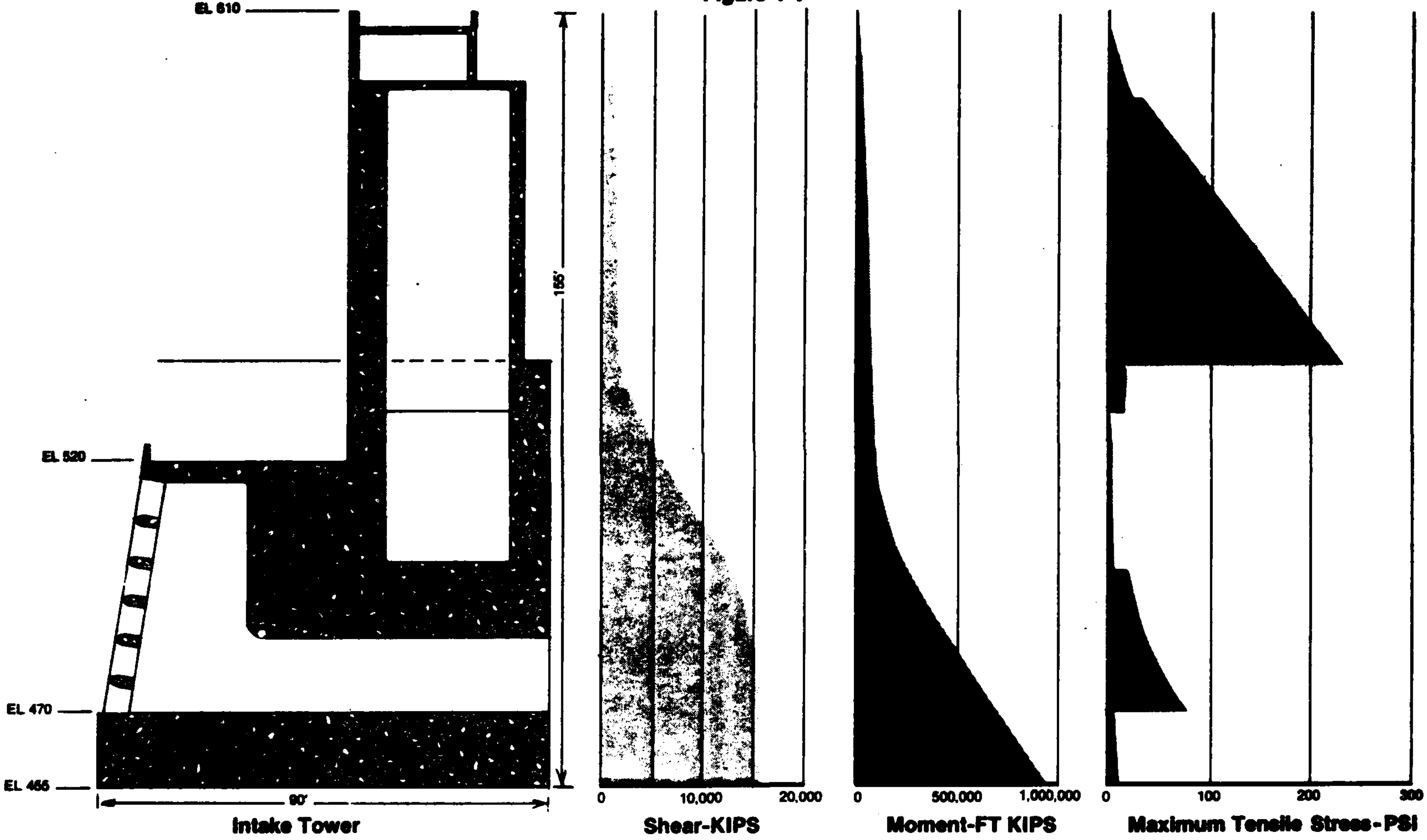
(3) Stress Analysis Requirements. Regulations in ER 1110-2-1806 require a dynamic response type of stress analysis for concrete structures in seismic zones 3 and 4, and in seismic zone 2 when the site-specific peak ground acceleration for the design earthquake is 0.15g or greater. Where stresses/forces/moments must be determined by dynamic analysis, current Corps guidance directs preliminary calculations be made using a simplified response spectrum method of analysis.

(4) Stress Analysis Method. The regulating outlet tower was analyzed using a two-mode added mass analysis. The method is described in detail in Technical Report SL-82-8, Seismic Analysis of Intake Towers, by Paul F. Mlakar and Patricia S. Jones, Structures Laboratory, U.S. Army Engineer Waterways Experiment Station, P.O. Box 631, Vicksburg, Mississippi 39180, October 1982. After calculating the length, mass, stiffness, and assumed mode shapes for the first and second natural modes of vibration of the tower, the natural periods and mode shapes were calculated using the computer program called "First and Second Frequencies of Non-Uniform Cantilever Using Rayleigh's Method." Documentation of the program is listed in appendix A of the above-mentioned report. Mass of the water inside and outside of the tower was determined using the added mass ratio graphs shown in the draft EM, Structural Analysis and Design of Intake Towers. When the natural periods and mode shapes of the tower were calculated, the ratio of the spectral acceleration/ground acceleration was determined using Seed's response spectrum for 28 rock records and 5 percent damping. The spectral acceleration was then scaled for the earthquake under analysis. Utilizing a cantilever beam model, static forces for predetermined segments of the tower were calculated using the conjugate beam method. Moments and shears for each of the mode shapes were calculated from internal equilibrium. Finally, probable maximum shears and moments were calculated by combining the nodal maximum shears and moments by the use of root mean square equations. Due to the complexity of the RO tower shape, more refined stress analysis will be required during the FDM phase.

(5) Stress Analysis Results. Figures 4-1 and 4-2 show the shears, moments, and maximum tensile stresses of the intake tower for the major and minor axis for the MCE. Since the analysis uses a cantilever beam as the structured model of the tower, no considerations are made for asymmetry. Using allowable concrete tensile stresses of 0.15 f'c = 600 psi for the MCE and 0.10 f'c = 400 psi for the OBE indicates reinforcement will only be required for temperature, shrinkage, and static loadings. Maximum tensile stresses were calculated using the formula, stress = $\frac{P}{A} \pm \frac{MC}{I}$.

Regulating Outlet Tower Dynamic Stress Analysis Results -- Major Axis
Maximum Credible Earthquake

Figure 4-1



Regulating Outlet Tower Dynamic Stress Analysis--Minor Axis
Maximum Credible Earthquake

Figure 4-2

(6) Seismic Isolation Joints. The RO structures will be designed to respond independently to seismic events. Special isolation joints may be required to be sure that the independent action occurs. The isolation requirements would be in addition to the water-stopped joints. Water stops will be designed in accordance with EM 1110-2-2102. Typical water stop details may not be sufficient for the seismic loadings. Further study will be required during the Feature Design Memorandum stage.

TRASHRACKS AND TRASH STRUCTURE

4-14 The concrete trash structure at the upstream face of the RO structure and the low flow bypass trashracks will be designed to resist a 5-foot head differential for normal conditions and a 10-foot head for overstress conditions.

BULKHEAD AND TRASH DECK

4-15 The bulkhead and trash deck will be designed for a 15-ton crane placed in any possible position.

BULKHEADS

4-16 One bulkhead for the intake passage entrances and one bulkhead for the low flow bypass entrance will be designed to resist 96.5 feet of head (pool at the standard project flood level at El. 566.5). The bulkhead will be used for maintenance purposes only. A fill pipe system will be used to equalize the pressure on both sides of the bulkhead to allow for gate removal. Either bulkhead will be placed or removed only when the hydrostatic heads are equalized on each side of the bulkhead. The low flow outlet bulkhead will use the same slots as the low flow bypass trash racks.

RO Transition Design

4-17 Design of the RO transition will be made using concrete, soil, rock, concrete dead load, and hydrostatic loads. Loading conditions will include construction conditions with fill, normal operating conditions, and extreme operating conditions.

RO Conduits Design

4-18 Design of the RO conduits will be based on the requirements of EM 1110-2-2902. Loads include rock, backfill, concrete dead load, and hydrostatic loads. Loading cases follow in table 4-3:

Table 4-3. Regulating Outlet Conduits Loading Cases.

Loading Case	Condition	Loads
I	Reservoir dry	Rock Load (RL) + Backfill Load (BL)
IIA	Debris Pool (both conduits empty)	RL + BL + External Hydrostatic (EH)
IIB	Debris Pool (one conduit operating)	RL + BL + EH + IH (one conduit)
IIIA	SPF (both conduits empty)	RL + BL + EH
IIIB	SPF (one conduit operating)	RL + BL + EH + IH

The loads for loading Case IIIA are shown on figure 4-3. The water surface elevation is assumed to be at the SPF level. Design will be optimized during the FDM level work.

Stilling Basin Design

GENERAL

4-19 Design of the stilling basin will be based on the requirements of EM 1110-2-2400. Loads include backfill, concrete dead load, and hydrostatic load.

WALL LOADING CONDITIONS

4-20 The loading conditions for the stilling basin walls are as follows:

(1) Case I, Stilling Basin Empty, Construction or Maintenance Condition.

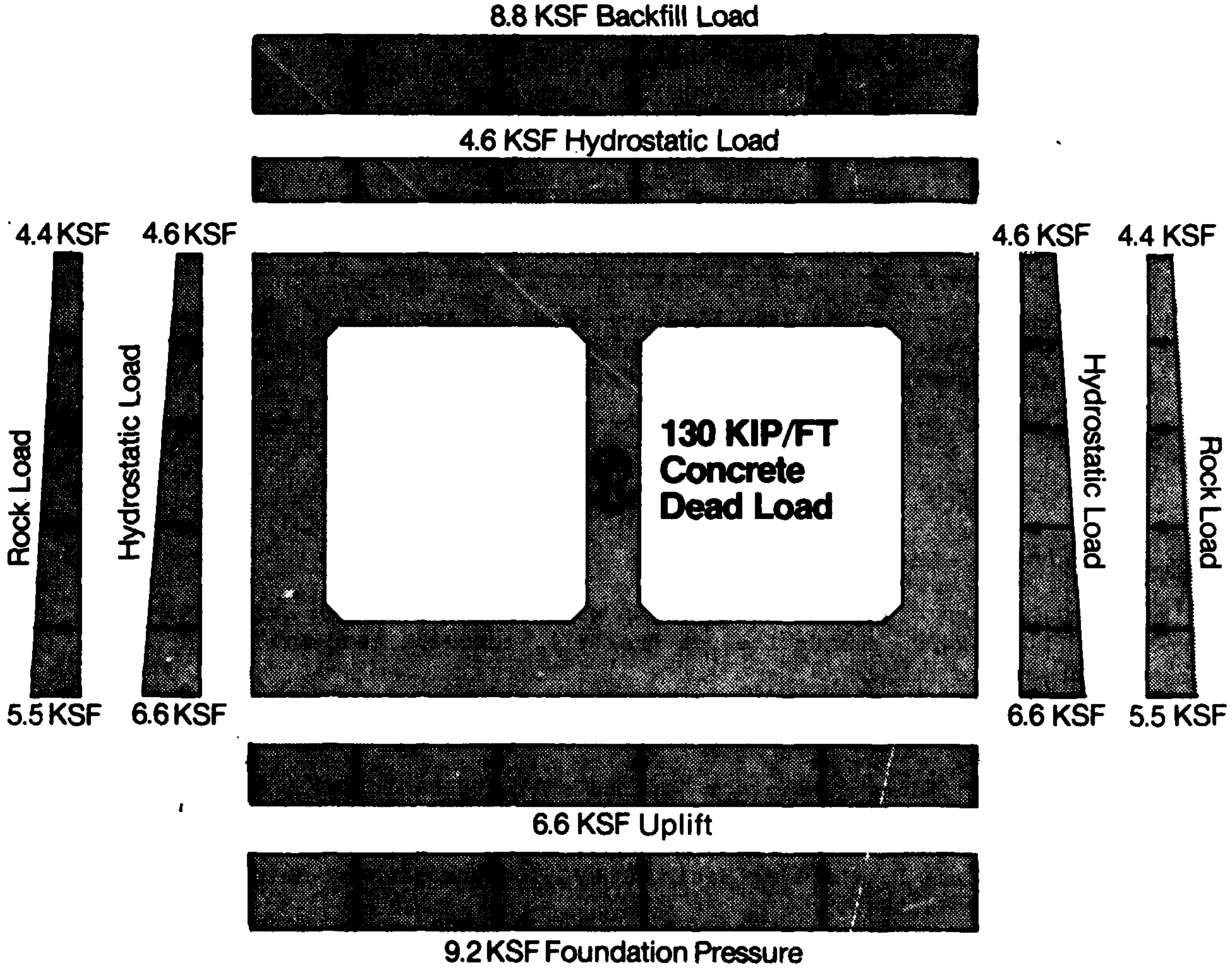
  (a) Backfill submerged to drain or higher if, during construction or maintenance, higher elevation is anticipated with stilling basin unwatered.

  (b) Backfill above drain naturally drained.

  (c) Surcharge, if applicable.

Regulating Outlet Conduits-Load Case IIIA

Figure 4-3



Note: Loads are unfactored

(d) Stilling basin empty.

(e) Full uplift varying uniformly from head in backfill to zero in stilling basin.

(2) Case II, Rapid Closure of Gates.

(a) Maximum reduction of discharge and tailwater expected to occur rapidly.

(b) Water surface inside stilling basin at tailwater corresponding to reduced flow conditions.

(c) Backfill submerged to elevation midway between tailwater before and after reduction (corresponding to 50 percent reduction by drainage).

(d) Backfill above level of submergence naturally drained.

(e) Uplift of uniform intensity across the base with pressure equal to reduced hydrostatic head in backfill.

(3) Case III, Stilling Basin Operating during Design Flood. This case is applied when there is no relatively impervious material separating backfill from tailwater and, therefore, no pressure relief by drainage in backfill is assumed.

(a) Water surface inside at hydraulic jump profile.

(b) Backfill submerged to tailwater.

(c) Backfill above tailwater is naturally drained.

(d) Uplift across base varying uniformly from tailwater at heel to value midway between tailwater and jump profile at toe (the latter corresponds to 50 percent relief of unbalanced pressure by floor drainage).

(4) Case IV, Seismic Loading Condition on the Walls.

(a) Stilling basin empty.

(b) Backfill naturally drained.

SPLITTER WALL

4-21 The splitter wall will be designed for the greater of the following two loading conditions.

(1) Condition I. Pool at spillway crest, water flowing on one side only, with static load from water on one side to lower envelope of jump pulsation on other side, and an impact allowance of 50 percent of the pulsating load.

(2) Condition II. One side of the stilling basin dewatered, tailwater at El. 458 (corresponds to 10-year storm event).

(3) Condition III. Seismic loading conditions on wall with stilling basin empty.

STOPLOGS

4-22 Structural, steel-framed stoplogs will be designed for dewatering one side of the stilling basin. With a 10-year storm event, the tailwater will be at El. 458, requiring design for a maximum hydrostatic head of 34 feet.

Approach Channel Wing Walls

4-23 The approach channel wing walls will be concrete gravity retaining walls. Loads will be concrete dead load, backfill, hydrostatic, and seismic (using seismic coefficients). Loading conditions and design will be in accordance with EM 1110-2-2502 and the draft EM, "Retaining and Flood Walls." Other wing wall configurations will be investigated in the FDM.

Access Bridge

4-24 The access bridge will be designed for the more restrictive load of an HS-20 truck or 15-ton crane. Seismic design will be based on the "Standard Specifications for Highway Bridges," published by the American Association of State Highway and Transportation Officials.

V. GEOTECHNICAL DESIGN

Foundation Conditions

OVERBURDEN

5-01 The overburden materials along the proposed outlet works alignment can generally be characterized as either older Quarternary alluvial or Recent alluvial deposits. The older alluvium overlies bedrock along the alignment from the approach channel to the stilling basin and is primarily composed of gravelly silty sand/silty sand to sandy gravel with increasing cobbles and boulders in the lower half of the deposit. The maximum thickness of the older alluvium is approximately 85 feet. Minimum thicknesses of this deposit are found in the area of the approach channel and near the downstream end of the RO conduits. Based upon caving problems encountered during drilling and in test trench exposures, the older alluvium is loosely consolidated. The Recent alluvium comprises the remaining portion of the outlet works alignment downstream of the stilling basin. These deposits consist typically of loosely consolidated silty sand and sand and reach a known depth of approximately 55 feet in the transition area between the stilling basin and the downstream outlet channel.

BEDROCK

5-02 The bedrock along the proposed outlet works alignment is the Sycamore Canyon member of the Tertiary-age Puente Formation. In general, the bedrock grades between silty sandstones and sandy siltstones. The coarsest and cleanest sandstones contain at least 15 percent silt and clay binder and the finest siltstones contain at least 20 percent sand. Using the Unified Soils Classification System (ASTM D 2487), the bedrock materials can generally be described as silty sands (SM) and sandy silts (ML). The bedrock is typically very dense, but generally uncemented.

Slope Design and Dewatering

GENERAL

5-03 Material properties used to establish temporary construction and final design slopes, in the overburden and bedrock, were determined from a range of phi (0) angles and cohesive strengths generated from R and S triaxial shear tests (Prado Dam - Outlet Works Relocation, Preliminary Geotechnical Analysis, October 1983; Prado Dam - Design Memorandum for Major Rehabilitation, Volume 1, July 1985). Slope stability analysis was conducted using the UTEXAS2 computer program developed by the Corps of Engineers Computer Aided Structural Engineering (CASE) Project Task Group. The Corps of Engineers' Modified Swedish Procedure (EM 1110-2-1902) was selected for slope stability analysis.

SLOPE STABILITY

5-04 Based upon a selected 0 phi = 34 degrees, a temporary construction slope of 1V on 1.5 H is required for the older alluvial materials along the outlet conduit. Bedrock consists of sandstones interbedded with sandy siltstones which are dense in nature, but are generally uncemented. An on-site investigation, however, revealed permanent bedrock slopes which approach 1V on 1H and have stood for over 40 years. Based upon a selected 0 = 34 degrees and c = 1,000 psf, a temporary construction slope of 2V on 1H and a final design slope of 3V on 2H is required to meet factor of safety requirements outlined in EM 1110-2-1902. A factor of safety of 1.4 was computed for slope stability during construction, assuming bedrock is dewatered.

DEWATERING

5-05 Subsurface investigations indicate dewatering of the alluvial material will likely be required in the area of the approach channel, stilling basin, and downstream outlet channel. The bedrock will probably be saturated and temporary cut slopes will likely lose a significant amount of strength if not dewatered. A dewatering system will be required to achieve a drawdown of groundwater below the excavated area to assure stability of the temporary cut slopes. Dewatering will also improve excavation characteristics of the bedrock. Site geology, the low permeability of the rock (1×10^{-1} to 5×10^{-3} ft/day), and the geometry of the RO conduit excavation lends itself well to a dewatering scheme involving horizontal drains and jet educator wellpoints or deep wells. Procedures outlined in Army TM 5-818-5 were used to develop an estimated educator spacing of 15 feet and was used only to the extent necessary to develop a rational cost estimate.

Foundation Design

BEARING CAPACITY AND SETTLEMENT

5-06 The foundation material is a sandstone, which ranges in hardness from moderately soft to moderately hard and is interbedded with layers of sandy siltstone. The sandy siltstone ranges in hardness from moderately hard to hard and is very competent. Under the dam, the sandstone/siltstone matrix dips steeply, 65 to 70 degrees upstream, and some bridging of the more competent siltstone over the sandstone can be expected.

5-07 Allowable bearing capacities, based upon a factor of safety of two to three, are frequently assumed to be one-third to one-fifth the unconfined compressive strength. Based upon a selected phi = 34 degrees and $c = 0.5$ ton/ft^2, an ultimate bearing capacity of 14 tsf with a computed factor of safety of 3.0 (construction load condition) was calculated for the intake structure foundation using the CBEAR (Computer Program for Bearing Capacity Analyses of Shallow Foundations) computer program developed by the Corps of Engineers' CASE Project Task Group. A minimum factor of safety of 3.0 is required. Additional investigation of the foundation for the intake structure will be required to determine the extent and properties of the bedrock in this area during design. Plate-bearing tests and consolidation tests will be conducted on undisturbed samples obtained from the proposed foundation area to better evaluate the allowable bearing capacity of the bedrock. This information will be used to determine the stress history of the bedrock and to evaluate settlement which may be expected. If an acceptable factor of safety cannot be achieved, alternative foundation designs to be considered include: overexcavation and backfill, piles, piers, or jet grouting.

FOUNDATION PREPARATION

5-08 Overburden material will be removed from rock surfaces and fractures within the excavation limits. The foundation surface will require dental concrete placement to provide a uniform base for the conduit. Prior to backfill placement, the foundation surface will be moistened to ensure a good bond between the foundation and backfill material.

Excavation

5-09 Excavation for the various outlet works features may be accomplished utilizing conventional methods. Overburden materials may be excavated with scrapers, loaders, and minimal dozer work. Results of seismic refraction surveys indicate the sandstone bedrock, represented by subsurface P-wave velocities ranging from 5,285 to 7,700 feet per second, is relatively dense. The wide range in velocities can be attributed to changes in lithology and the degree of cementation of the bedded sediments. When dry, bedrock ranges in hardness from moderately soft to moderately hard and may require ripping prior to excavation by conventional methods. Blasting should not be required, however.

Bedrock would be encountered during excavation for the approach channel intake structure RO conduit an stilling basin. In the RO conduit area where practicable, bedrock will be excavated vertically and used as a form for the placement of concrete for the conduit in order to reduce excavation and backfill quantities and to eliminate forming costs. Vertical cut slopes of moderate height have successfully been used in massive soft rock formations and in highly consolidated soil units. If necessary, vertical slopes will be stabilized with 2-inch-thick fiber reinforced shotcrete to prevent degradation of the slope after exposure to the atmosphere. Where necessary, rock bolts and drains will be intalled after the shotcrete has been applied. A detailed evaluation of the stability of the slope will be performed during feature design. Plate 6 details excavation and backfill for the RO conduit.

Backfill

5-10 Backfill for the RO conduit will be obtained by stockpiling material obtained from the RO conduit excavation and blending with material obtained from borrow sites to produce a material conforming to Zone II type embankment fill. Compactive effort must yield minimum in-place densities of 95 percent maximum density determined by ASTM D 698-70.

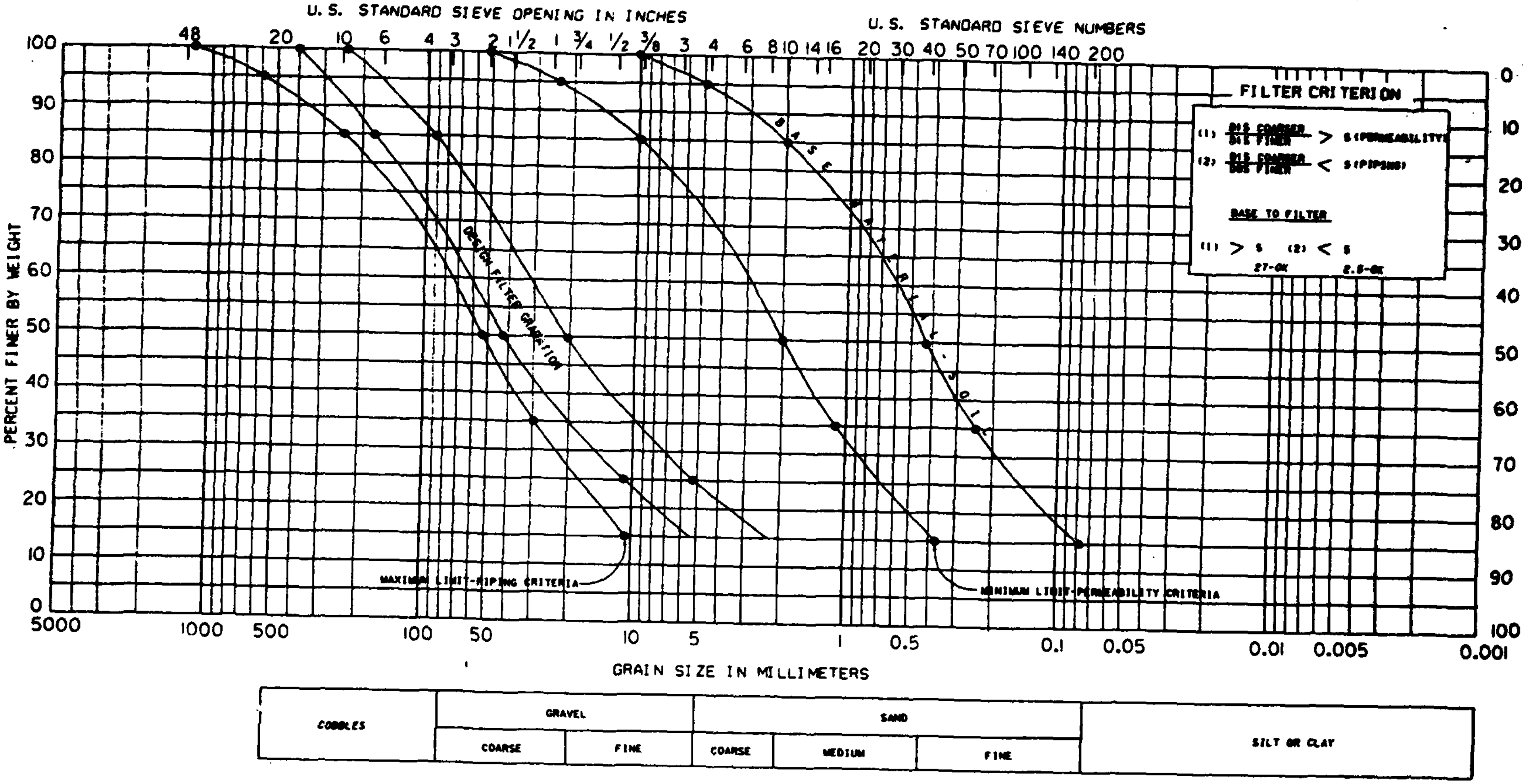
Riprap Design

5-11 Riprap design criteria used to calculate rock size, gradation, and blanket dimensions for the downstream outlet channel were in accordance with EM 1110-2-1601 and ETL 1110-2-120. A design velocity of 14.8 ft/s was used to calculate a maximum rock size of 44 inches (W100 = 4,400 pounds). The riprap was sized based upon the velocity produced by maximum discharge and minimum curve radius. This procedure gives a conservative stone size suitable for computing GDM costs. The riprap should be designed using conditions which are anticipated for each reach of the channel to optimize cost. Design criteria for the filter blanket were in accordance with EM 1110-2-1901. Figure 5-1 shows the gradation envelope for the filter. Plate 8 details gradation requirement and blanket dimensions for the rock riprap.

Seismic Design Parameters

5-12 Seismic design parameters for Prado Dam were determined in a report titled Seismicity Report, Prado Dam, Corona, California, dated 7 May 1981, by Jeffrey A. Johnson, Inc., of Pacific Palisades, California. That report is published in table 3 of appendix B of Design Memorandum No. 1, Prado Dam Rehabilitation. The operating basis earthquake (OBE) is taken as a magnitude 8+ earthquake located on the San Andreas Fault, 44 kilometers distant. The maximum credible earthquake (MCE) is taken as a magnitude 6.5 to 7.0 located on the Whittier Fault, 2.5 kilometers distant. Based on these design

earthquakes, the recommended seismic design parameter for the OBE is a peak horizontal acceleration of 0.30 g with a 40 second duration of acceleration greater than 0.05 g. For the MCE, the recommended seismic parameter is a peak horizontal acceleration of 0.60 g with a 30 second duration. A review of these parameters showed that the values are reasonable when considering the horizontal earthquake activity, distances from known faults, and commonly accepted attenuation curves.



FILTER DESIGN - DOWNSTREAM CHANNEL

FIGURE 5-1

VI. MECHANICAL DESIGN

General

6-01 This section describes the mechanical equipment and systems required for operation of the Prado Dam Project, and presents basic data, design criteria assumptions, and methods that will be used in the design of the mechanical features. This equipment includes the regulating outlet (RO) gates and operating machinery, low flow slide gates, bulkhead gate operation, overhead bridge crane, emergency generator, RO and low flow withdrawal conduit fill pipes, elevator, forebay water level sensor, ventilation system, deckwash system, structural drains, sanitary system, compressed air supply system, and other facilities.

RO Slide Gate System

6-02 The RO gates are shown on plate 9. The system will consist of six 9-foot 9-inch-wide by 14-foot 9-inch-high RO gates. The bonnets and frames for the gates were designed for an internal and external load equal to the maximum pool pressure without exceeding a basic stress of 16,200 psi, using ASTM A-36 steel. External tension anchors, which will transfer the compressive load to the concrete will be used to prevent the gate frame from collapsing inward if leakage occurs around the conduit liner. Two design heads were used for the calculations: structural design head of 126 feet was measured from gate centerline to maximum pool; operational design head of 95 feet was measured from the gate centerline to maximum operating pool. The seals will be an aluminum-bronze alloy on the leaf and stainless steel (ASTM A-314-72, Type 303) on the frames and sills, as recommended by "Sliding and Friction Tests of Bearing Materials," performed in July 1960 by the University of Idaho, Engineering Experiment Station, Moscow, Idaho, for the U.S. Army Corps of Engineers, Walla Walla District, Washington. Both of these materials are weldable and machineable, therefore, repairs and attachment by welding can be performed. The bottom seal will be a stainless steel-tipped gate to a babbitted (ASTM B23-83) sill. A starting coefficient of friction of 0.6 was used for the design

calculations. The RO slide gates will be operated by hydraulic cylinders. Design of the cylinders, flanges, cylinder heads, and other appurtenant parts will be in compliance with section 8 of the ASME Boiler and Pressure Vessel Code for Unfired Pressure Vessel. The gate stem will be made of solid stainless steel, Type 304. The gate leaf will be designed for the maximum design head at a maximum basic stress of 16,200 psi using ASTM A-36 steel. An indicator rod connected to the gate leaf will be provided to show the gate opening.

Low Flow Slide Gates

6-03 The low flow slide gates will be 2 feet wide by 3-1/2 feet high. The design pressures of these gates will be the same as those for the RO gates. The gates will be operated by hydraulic cylinders.

Hydraulic Operating Equipment

6-04 Operation of the RO slide gates and low flow slide gates will be by hydraulic cylinders. Local and remote control push button stations will be provided as described in section 7. Gate position indicators will be provided. Three hydraulic systems will be provided, two systems for each set of three RO gates and one system for the low flow gates. The hydraulic equipment for each of these systems will be as shown on plate 7. Each hydraulic system will operate at 2,000 psi. The test and maximum pressures for the systems will be 3,000 psi. The pumps will be rated at 15 gallons per minute (gpm) at 2,000 psi for the RO system and 2.8 gpm at 2,000 psi for the low flow system. The capacities of each of the respective systems, with one pump running, will provide a gate lift speed of approximately 1 foot per minute (fpm) for one gate with a pump speed not in excess of 1,800 revolutions per minute (rpm). Each hydraulic system will be valved in such a manner that one pump and motor can be removed while the other pump is operating. Additionally, the pumps will be valved so that both pumps can be operated simultaneously. The motors, pumps, and pressure relief valves will be mounted directly to the respective oil storage reservoir. The oil reservoir will be sized to contain the volume of oil required to store all of the oil used when closing all gates. The reservoir capacity for the RO hydraulic system will be 500 gallons. The low flow gate hydraulic system reservoir capacity will be 20 gallons. The oil storage reservoirs will include suction line indicating filters, return line filters, air vent, and sight gauge. The piping and fittings will be steel rated at 3,000 psi. Solenoid-controlled four-way valves will control hydaulic fluid to raise or lower the RO and low flow gates. A hydraulic pressure switch will disconnect the pump motor circuit when the gate leaf hits the bottom seal or the bonnet cover.

RO and Low Flow Slide Gate Removal

6-05 A 15-ton overhead bridge crane will be used in the gate room to disassemble and remove the slide gates as necessary for repair or maintenance. The crane will have a coverage envelope large enough to

place different parts of a disassembled gate and operator in areas of the gate room to facilitate "on-site" repair, if feasible.

Bulkhead Placement and Removal

6-06 The bulkheads will be installed and removed by mobile crane on the El. 520 deck. The bulkheads will only be installed or removed in low water periods. When not in use, the bulkheads will be stored in a raised position below the deck in the bulkhead slots.

Emergency Generator Plant

6-07 The emergency generator will be a diesel generator located in the control room at El. 596. It will supply emergency power to the RO gate operating equipment, gate room, lighting system, ventilating equipment, and other loads as described in section 7.

Elevator

6-08 A vertical lift, traction-type elevator will be provided to transport personnel from below the intake deck to the machinery room floor. The elevator will be powered from a 460 volt, 3-phase, 15 horsepower, motor-generator set mounted in an elevator equipment room above the elevator. The travel speed will be 350 feet per minute. There will be one emergency landing at approximately the midpoint of travel. The elevator will have a 2,000-pound load capacity.

Deck Wash Water System

6-09 An electric motor-driven pump with a capacity of 50 gpm at 50 psi will supply hose stations on the access road. Water will be supplied from the reservoir. A duplex strainer will be installed on the suction side of the deck wash pump. Control will be manual start/stop with a pressure relief bypass.

RO Conduit Fill Pipes

6-10 Water will be supplied from the pool to a header pipe in the gate room. Individual pipes will supply water from the header to fill the RO conduit between the slide gates and the bulkheads to equalize the head on the bulkheads prior to removal. Control valves will be located in the gate room.

Ventilation

6-11 Fresh air will be supplied to the RO machinery room via ductwork mounted in the control tower. A minimum of one air change per hour will be supplied to the machinery room. Exhaust will be vented through louvers near the roof.

Sanitary Facilities

6-12 An electric incinerating toilet will be provided in the service building area. It will be exhausted to the atmosphere. No sewage disposal site will be required.

Structure Drains

6-13 The machinery room will be sloped to floor trench drains around the perimeter of the room. This trench will drain by gravity to the RO conduit.

Compressed Air

6-14 A single 5hp portable air compressor will be provided to supply compressed air at 100 psi. This compressor can be used throughout the project for service air requirements.

Other Facilities

6-15 Unit heaters will be provided in the control room to maintain an indoor temperature of 55 degrees at a winter design temperature of 32 degrees (ASHRAE 97.5 percent dry bulb for Riverside-March AFB). A waterless hand cleaner will be provided in the restroom. No water will be required for the toilet or cleanup. No provision will be made for potable water. If drinking water is required, a bottled water dispenser could be utilized.

VII. ELECTRICAL DESIGN

General

7-01 The electrical design will consist of the project power supply, emergency power supply, project power distribution and protection, power and control for electro-mechanical equipment and loads, lighting, communications, security, grounding, and corrosion mitigation.

Project Power Supply

NORMAL POWER

7-02 Electrical power for the project will be supplied from a 3-phase distribution line extension owned by Southern California Edison. An outdoor substation will be located on a concrete pad near the dam abutment. The substation will consist of a loadbreak fused disconnect switch, surge arresters, 3-phase oil-filled transformers, and a steel outdoor pad-mounted enclosure. The secondary service will be 480V, 3-phase, delta.

EMERGENCY POWER

7-03 Electrical power during emergencies (i.e., no utility power source) will be generated on-site by a diesel engine driven generator. The engine will be equipped with automatic start-stop controls to ensure availability of power at all times. An automatic transfer switch will ensure continuity of 480V 3-phase service. The set will generally follow the requirements of CEGS-16264.

Project Power Distribution System

480 VOLTS

7-04 The power for the intake tower will be distributed at 480V, 3-phase. Power will be from the secondary side of the utility transformer and supply motor control center DQ1 (see pl. 10). DQ1 will supply all loads required in the intake structure. It will consist of a split bus with an automatic transfer switch in between the emergency bus and the total normal bus. All essential loads will be on the emergency bus. The motor control center will be per CE-2205.05.

208Y/120 OR 120/240 VOLTS

7-05 Power will be obtained from 480V step-down general purpose lighting transformers. They will supply lighting panelboards that feed loads such as lighting, receptacles, incinerating toilet, and other small loads. Panelboards will be industrial-type utilizing industrial E-frame circuit breakers. Transformers will conform to applicable NEMA and ANSI standards.

Control Systems

MACHINERY AND EQUIPMENT

7-06 The RO slide gates and low flow slide gates will have open-stop-close controls with indicating lights and position indications. They will be capable of local manual or remote manual operation from El. 596. The hydraulic pumping sets will have local-remote on-off control with automatic shutoff at a set high pressure. Controls will be designed for extremely safe and reliable operation. Controls for the ventilation system will be manual on-off controllable at El. 596. The deck wash pump will be operable locally and remotely from the deck.

RESERVOIR SENSING

7-07 A float switch with local and remote readouts will be utilized for sensing the pool level. A recorder will be provided, if deemed necessary. Coordination will be accomplished with the U.S. Geological Survey.

Telephone System

7-08 Telephone outlets will be provided in the gate room, El. 596, and in the elevator. Service for an outside line will be obtained from a line extension owned by the local servicing utility, Pacific Bell.

Security

REGULATORY REQUIREMENTS

7-09 Applicable portions of certain regulations will be incorporated into the design. These regulations are: AR 190-51, "Security of Army Property at Unit and Installation Level"; DARCOM Supplement, FM 19-30, "Physical Security"; and TM 5-853-1, "Designing for Security."

LOCAL REQUIREMENTS

7-10 Special requirements will be added to mitigate vandalism indigenous to the area.

Lighting System

NORMAL OPERATION AND MAINTENANCE REQUIREMENTS

7-11 Illumination will be provided as necessary for safe operation and maintenance of the facilities. Luminaires will be of the energy efficient types, including high-pressure sodium and fluorescent light sources. Color rendition will be fully coordinated with the task involved.

EMERGENCY

7-12 With the availability of the emergency generator, emergency type luminaires will not be utilized.

SECURITY

7-13 Vandal resistant luminaires will be strategically placed for security illumination during darkness.

Raceway, Wire and Cable

RACEWAYS

7-14 Conduit will be used to the fullest extent: it will be of the rigid and intermediate types.

WIRE AND CABLE

7-15 CE 1404.04 will be the guide for specifying wire and cable.

Grounding System

7-16 All metallic structures and equipment will be bonded together with bare copper cables. This network will be brought out to the pool where a ground mat will be buried.

Corrosion Mitigation

7-17 A water analysis will be made prior to the corrosion mitigation study. The analysis, study, and recommendations will be made during the FDM level.

VIII. OPERATIONS AND MAINTENANCE CONSIDERATIONS

General

8-01 This section describes the operation procedures, maintenance requirements, and expected costs for operations and maintenance, and for the various mechanical and electrical equipment associated with the Prado Dam outlet works.

Operations

GENERAL

8-02 In 1936, Prado Dam was authorized by Congress as a flood control project. The Los Angeles District, Corps of Engineers, has operated and maintained the flood control facility since its completion in 1941. Operation of the existing outlet works follows an established procedure which is anticipated to change very little after the proposed outlet works is constructed.

CURRENT OPERATIONS

8-03 Prado Dam is now operated to accommodate two main conditions.

(1) Normal Operating Conditions. When there is no precipitation in the basin, day-to-day flows into the reservoir are fairly constant. A dam operator reports to the site for an 8-hour shift, Monday through Friday. The operator adjusts the gate to maintain flows that are directed by the Reservoir Regulation Section, Hydrologic Engineering Branch, Los Angeles District. Other operator duties include checking equipment and performing routine maintenance.

(2) Rainy Conditions. When it rains, the dam operator works 7 days a week. An additional person is assigned to work nights when necessary to provide 24-hour operation. As under the normal

operating conditions, the Reservoir Regulation Section determines the flows that pass through the outlet works.

(3) Debris Pool. A debris pool is maintained at El. 490 during the wet portion of the year. During the dry portion of the year, the pool is drawn down as determined by the Reservoir Regulation Section. Some years the pool is drawn down low enough to create a "run of the river" condition. The drawdown period may vary from May in a dry year to August in a wet year. The pool is built up again with the "first heavy rain" which may occur as early as mid-October or as late as the end of December.

ANTICIPATED OPERATIONS

8-04 The only operation change anticipated will be simpler gate operation. Gates will be remotely operated from the control room of the intake tower at El. 596. Flows below 30,000 cfs will pass through the regulating outlets, low flow bypasses, or some combination of outlets. The system will have the capability to open or close any individual gate, or combination of gates, although simultaneous gate movements will be restricted to three gates at a time.

FLOODFLOWS

8-05 When inflows are high enough to cause the forebay elevation to rise to the spillway crest, all slide gates will be closed. All flow will then be discharged over the spillway.

GENERAL OPERATING COSTS

8-06 Future operating costs are anticipated to remain the same as current operating costs. The cost estimate is based on the following:

Dam operator wages, benefits, etc.	$60,000
Vehicle	3,000
Temporary help -flood flows, etc.	30,000
Total	$93,000

INSPECTION AND MONITORING

8-07 There are several inspection programs which may include personnel other than project forces. These activities include but are not limited to the following:

(1) Periodic inspections.

(2) Evaluations.

(3) Bridge inspections.

(4) Reservoir monitoring.

(5) Surveys.

(6) Seismic service (USGS).

Annual cost for these activites are listed in table 8-1.

Table 8-1. Annual Inspection and Monitoring Costs.

Item	Estimated Annual Cost
Periodic inspection	$15,000
Evaluations	8,000
Bridge inspection	1,000
Reservoir inspection	3,000
Survey monitoring	5,000
Seismic service (USGS)	1,000
Total	$33,000

Maintenance

DEBRIS

(1) General. Debris at Prado Dam consists mostly of an occasional fallen tree, heavy branches, brush, and matted grass (mostly after the first heavy rain of the year). The debris is caught by the log boom or is deposited along the shoreline when the pool recedes.

(2) Removal. Currently, two contracted crews pick up the debris once a year. The work is performed in the dry season and takes about a week. The debris is collected from the upstream face of the dam and along the levee at the log boom. Each removal crew consists of three laborers who use a 20-yard trash compactor truck. The debris is disposed at a landfill off-site.

(3) Cost. Currently one removal crew charges $42 per hour and the other $54 per hour. Total charge for both crews for 1 week would be $3,840. These values are very low and could easily be twice as high. For estimating purposes, $5,000 per year will be used.

SEDIMENT

(1) General. Sediment infilling at Prado Dam is an important maintenance concern. Storage capacity at the spillway crest decreased 26,600 acre-feet from 1941 to 1979. Storage capacity and average sediment accumulation per year are shown in table 8-2.

Table 8-2. Storage Capacity and Average Sediment Accumulation.

Date of Capacity Computation	Storage Capacity (acre-feet)	Change in Capacity (acre-feet)	Elapsed Time	Average Sediment Accumulation Per Year	
				Acre-Feet	CY
Sep 1941	222,840	---	---	---	---
Aug 1960	216,960	5,880	18 yr, 11 mo	311	500,000
Sep 1969	198,222	18,738	9 yr, 1 mo	2,063	3,300,000
Dec 1979	196,235	1,987	10 yr, 3 mo	194	310,000
	Total	26,605	38 yr, 3 mo		
Yearly Average 1941 to 1979				700	1,100,000

(2) Removal. Sediment removal is not anticipated except possibly in the approach channel. Sediment is currently removed upstream of the trash racks on a yearly basis. Since the inverts of the new outlet works will be 10 feet higher than the existing outlet works, sediment removal should not be necessary initially. Operating experience will determine when and how much sediment will need to be removed.

(3) Cost. The cost for removing sediment from the approach channel is included in the general operations cost.

FACILITIES

8-08 Maintenance of the grounds, access bridge, project roads, and concrete and steel structures has an estimated annual cost of $6,000.

MECHANICAL

(1) Regulating Outlet (RO) Slide Gates. The maintenance of the RO slide gates will follow a consistent repair and inspection schedule. Quarterly, annual, and 5-year inspections are carried out by various operations and engineering personnel. Minor repairs are estimated to occur every 10 years (typically motor/pump failure, valve replacement, or gland replacement). Major repairs due to seal failure or gate tip failure would be expected every 30 years. The latter repairs would require removal of the gate leaves.

(2) Low Flow Slide Gates. The low flow slide gates will follow a maintenance pattern similar to that for the RO slide gates. Minor repairs such as hydraulic motor/pump/valve failure or gland replacement are expected every 10 years with major repairs to the gate seals or gate tip expected every 30 years. The low flow slide gates will also be inspected on the same schedule and at the same time as the RO slide gates.

(3) Other Mechanical Equipment. Other maintenance is considered normal for each mechanical system. The proposed mechanical maintenance items and costs are shown on table 8-3. Costs are annualized over 100 years at 8 7/8 percent interest.

ELECTRICAL

8-09 Most of the equipment will require scheduled preventative maintenance (PM). Maintenance will range from checking the equipment's operation to routine replacement of parts (e.g., from an "on" and "off" operational check to the replacement of load contacts of contactors). The expected life of nearly all equipment is less than the 100-year life of the structure. Therefore, much of the equipment will be replaced from one to five times. Table 8-4 lists the equipment, with the expected life, PM requirement, and replacements required. The most difficult figure to develop will be "unscheduled" maintenance, i.e., equipment failure in a statistical form. An average from similar projects will be the best source for this information. There is also a "reverse" bell-curve in action for each project, i.e., maintenance will be higher than normal when the equipment is new and near end-of-life.

Table 8-3. Annualized Mechanical Maintenance and Replacement Costs.

Item	Description	Cost
RO gates, operators, hydraulics, etc.	9-foot 9-inch by 14-foot 9-inch RO slide gates, gate frame, cylinders, hydraulic operating machinery, etc. Six service gates. Design head - 126 feet	$7,500
Low flow slide gates	2-foot by 3-foot 6-inch low flow slide gate including operator (two required)	1,000
Emergency generator tank, etc.	Provide emergency power for operating RO slide gates, lights, low flow bypass	1,000
Elevator	Access to RO gate room, removal of gate, machinery, etc., for maintenance	3,000
Floatwells	Forebay water level sensors	100
Water Supply	Fill RO conduit between slide gates and bulkhead, deck wash system	300
HVAC	Intake structure, gate rooms, minimum one air change/hr, ductwork must go up access	500
Hoists/Cranes	Maintenance in gate room, removal of gates and operators, etc.	1,000
Sanitary Facilities		500
Air Compressor		300
		$15,200

Table 8-4. Annualized Electrical Maintenance and Replacement Costs.

Items	Description	Cost
DQ 1 Motor control center	a. 600V, 3-phase, 600A, four stacks with combination starters and circuit breaker compartments automatic transfer switch.	
	b. 35-year life (7-year life on contacts and coils).	
	c. PM* required.	$ 350
	d. Two replacements required.	350
Motors and generator	a. 460V, 3-phase, TENV and drip proof.	
	b. 20-year life (7-year life on bearings).	
	c. PM required.	
	d. Four replacements required.	
Transformers	a. 480-208Y/120V, 3-phase, dry-type.	
	b. 50-year life.	
	c. PM required.	350
	d. One replacement required.	10
Lighting panelboard	a. 208Y/120V, 3-phase, 100 amp, 24 circuits.	
	b. 35-year life.	
	c. PM required.	350
	d. Two replacements required.	10
Lighting ballasts	a. Two-lamp, 118-120V.	
	b. 10-year life.	
	c. PM not required.	
	d. Nine replacements required.	60
Lighting lamps	a. 4-foot fluorescent.	
	b. 10-year life (20,000-hour standard rating).	
	c. PM not required.	
	d. Nine replacements required.	20
Unscheduled	All equipment possible.	4,400
TOTAL		$7,900

* PM = preventative maintenance.

Summary of Operation and Maintenance Costs

8-10 Total annualized operation and maintenance costs for the Prado Dam outlet works are as follows:

Table 8-5. Summary of Operation and Maintenance Costs.

Item	Annual Cost
General operation	$ 93,000
Inspection and monitoring	33,000
Debris removal	5,000
Facilities	6,000
Mechanical	15,000
Electrical	8,000
	$160,000

IX. COST ESTIMATE

Cost Estimate

The construction cost detail for the outlet works is shown on table 9-1. All costs are based on August 1987 price levels. Unit costs are derived from applying judgment to recent bid costs on similar work and other historical cost data.

Prado Outlet Works Cost Estimate 16 September 1987

Table 9-1

Item	Unit	Quantity	Unit Cost - $	Item Cost - $	Feature Subtotal - $
1. Mobilization	LS	1	1,000,000.00	1,000,000.00	
					1,000,000.00
2. Clearing and Grubbing (includes d/s channel)	AC	28	800.00	22,400.00	
					22,400.00
3. Diversion and Cofferdams					
a. dewatering	LS	1	100,000.00	100,000.00	
b. care of water	LS	1	100,000.00	100,000.00	
c. backfill	CY	3220	2.00	6,440.00	
					206,440.00
4. Project Roads					
Intake access road	LF	1,000	225.00	225,000.00	
					225,000.00
5. Excavation (Intake)					
a. Unclassified	CY	515,000	2.50	1,287,500.00	
b. Slope Treatment					
(1) shotcrete	CY	150	350.00	52,500.00	
(3) fencing	LF	1,800	25.00	45,000.00	
					1,385,000.00
6. Excavation (cut and cover)					
a. Unclassified	CY	451,000	2.50	1,127,500.00	
b. Slope Treatment					
(1) shotcrete	CY	940	350.00	329,000.00	
(2) fencing	LF	2,000	25.00	50,000.00	
					1,506,500.00
7. Excavation (Stilling Basin)					
a. Unclassified	CY	125,000	2.50	312,500.00	
b. Slope Treatment					
(1) shotcrete	CY	150	350.00	52,500.00	
(2) fencing	LF	1,300	25.00	32,500.00	
					397,500.00
8. Downstream Channel					
a. Unclassified excavation	CY	256,000	1.20	307,200.00	
b. Riprap	CY	28,300	12.00	339,600.00	
c. Berm	CY	28,500	2.00	57,000.00	
					703,800.00
9. Backfill					
Select	CY	477,000	2.00	954,000.00	
					954,000.00
10. Concrete					
a. Intake Structure	CY	22,700	225.00	5,107,500.00	
b. Intake guide walls	CY	8,400	100.00	840,000.00	
c. Tower access bridge	LF	220	1,000.00	220,000.00	
d. Cut and Cover Conduits	CY	19,100	225.00	4,297,500.00	
e. Stilling basin structure	CY	12,400	225.00	2,790,000.00	
f. Transition	CY	16,500	225.00	3,712,500.00	
g. Architectural Features (Doors, interior partions and finishes)	LS	1	50,000.00	50,000.00	
					17,017,500.00
11. Miscellaneous Metal & Structural Steel					
a. Handrails, stairs & grating	LB	25,000	2.00	50,000.00	
b. Low flow piping	LB	86,200	2.00	172,400.00	
c. RO bulkheads & guides	LB	40,000	2.50	100,000.00	
d. Air pipe for gates	LB	48,000	2.00	96,000.00	
e. Trash Boom	LS	1	50,000.00	50,000.00	
					468,400.00
12. Mechanical Equipment					
a. Floatwell mechanisms	LS	1	25,000.00	25,000.00	
b. Water supply	LS	1	25,000.00	25,000.00	
c. Drains	LS	1	15,000.00	15,000.00	
d. RO gates, frames, cylinders & operators	LS	1	2,000,000.00	2,000,000.00	
e. Generator & Fuel tank	LS	1	70,000.00	70,000.00	
f. Sanitary Facilities	LS	1	10,000.00	10,000.00	
g. Heating & ventilating	LS	1	25,000.00	25,000.00	
h. Elevator	LS	1	200,000.00	200,000.00	
i. Hoists/cranes	LS	1	80,000.00	80,000.00	
j. Low flow valves	LS	1	70,000.00	70,000.00	
k. Air compressor	LS	1	25,000.00	25,000.00	
					2,545,000.00
13. Electrical Equipment	LS	1	275,000.00	275,000.00	
					275,000.00
Sub-Total Const. costs					$26,706,540.00
Contingency	15.0%	$4,005,981.00			
Total Construction Costs		$30,712,521.00			

X. CONSTRUCTION CONSIDERATIONS

General

10-01 The proposed construction schedule for the Prado Dam outlet works is shown on figure 10-1. The principal considerations controlling the construction schedule of all phases of construction were the weather and the need to keep the existing dam operational throughout construction. Construction will be completed in three stages over a 2-year period. Plate 11 shows a cross section of the upstream cofferdam. Protection will be provided to a maximum elevation of 525 feet at all times, with temporary diversion being provided by the dam's existing outlet works. The existing outlet works would remain fully operational and would be utilized for dewatering the reservoir to allow construction of the dike along Highway 71 at low elevevation.

First Stage Construction

10-02 Stage 1 construction is scheduled to begin in October and is the most critical of the three stages as it consists of work within the flood basin. Stage 1 construction consists of excavation for the intake structure, conduit transition, stilling basin, and the downstream outlet channel. Much of the excavation scheduled during Stage 1 is at an elevation above 525 feet. Excavation can begin prior to the completion of the cofferdam in these areas. The cofferdam must be in place as excavation proceeds below the 525-foot elevation for the intake structure and conduit transition. When excavation is complete, concrete work can begin in three areas: intake structure, conduit transition, and stilling basin. Plate 11 details Stage 1 construction.

PRADO DAM OUTLET WORKS CONSTRUCTION SCHEDULE

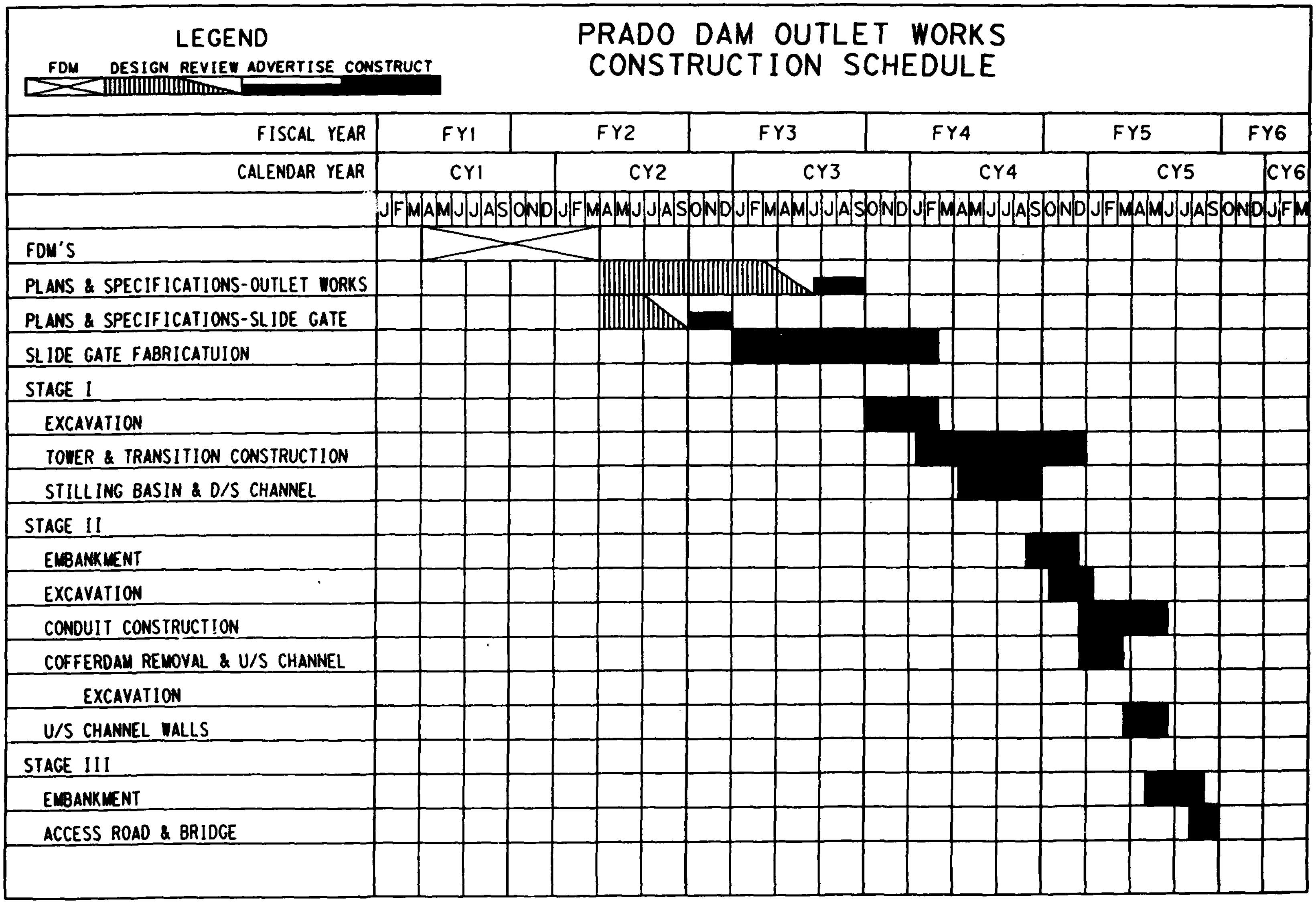


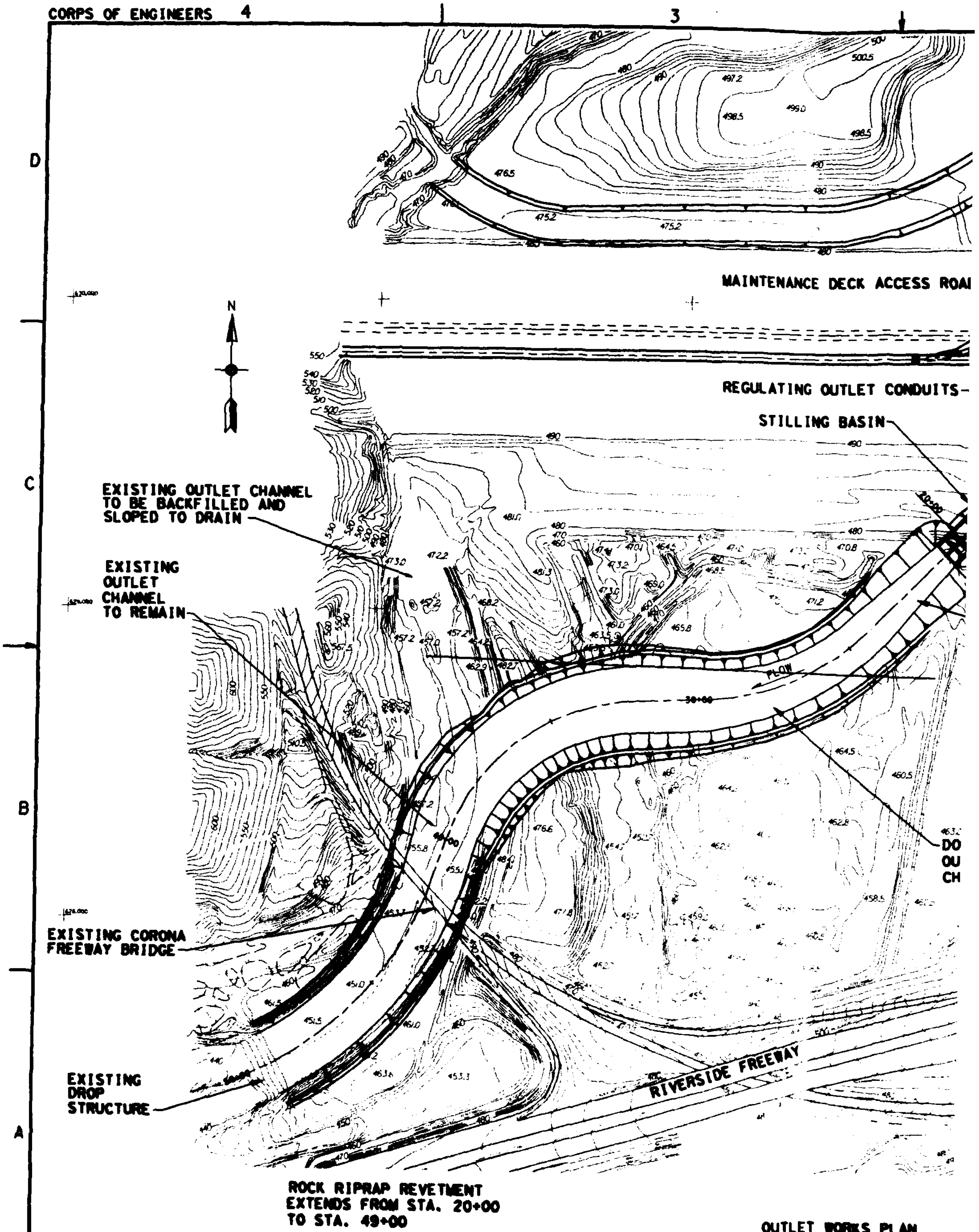
FIGURE 10-1

Second Stage Construction

10-03 Stage 2 construction includes placement of embankment fill around the intake structure and conduit transition. Once the embankment fill reaches El. 525 feet, excavation for the RO conduit and upstream approach channel will be staged in a manner that will allow the wing walls of the intake structure to be constructed. A cross section of the upstream approach channel is shown on plate 3. Concrete placement for the conduit and intake structure wing walls would begin as soon as excavation for each is completed. Placement of fill around the stilling basin and placement of rock riprap for the outlet channel will continue during this stage. Plate 12 details Stage 2 construction.

Third Stage Construction

10-04 Stage 3 construction includes placement of embankment fill to complete the dam's cross section and construction of the access road and access bridge from the crest of the dam to the intake structure. Excavated areas with temporary construction slopes will be sloped back to permanent design slopes. Plate 13 details Stage 3 construction.


CORPS OF ENGINEERS
4
3
D
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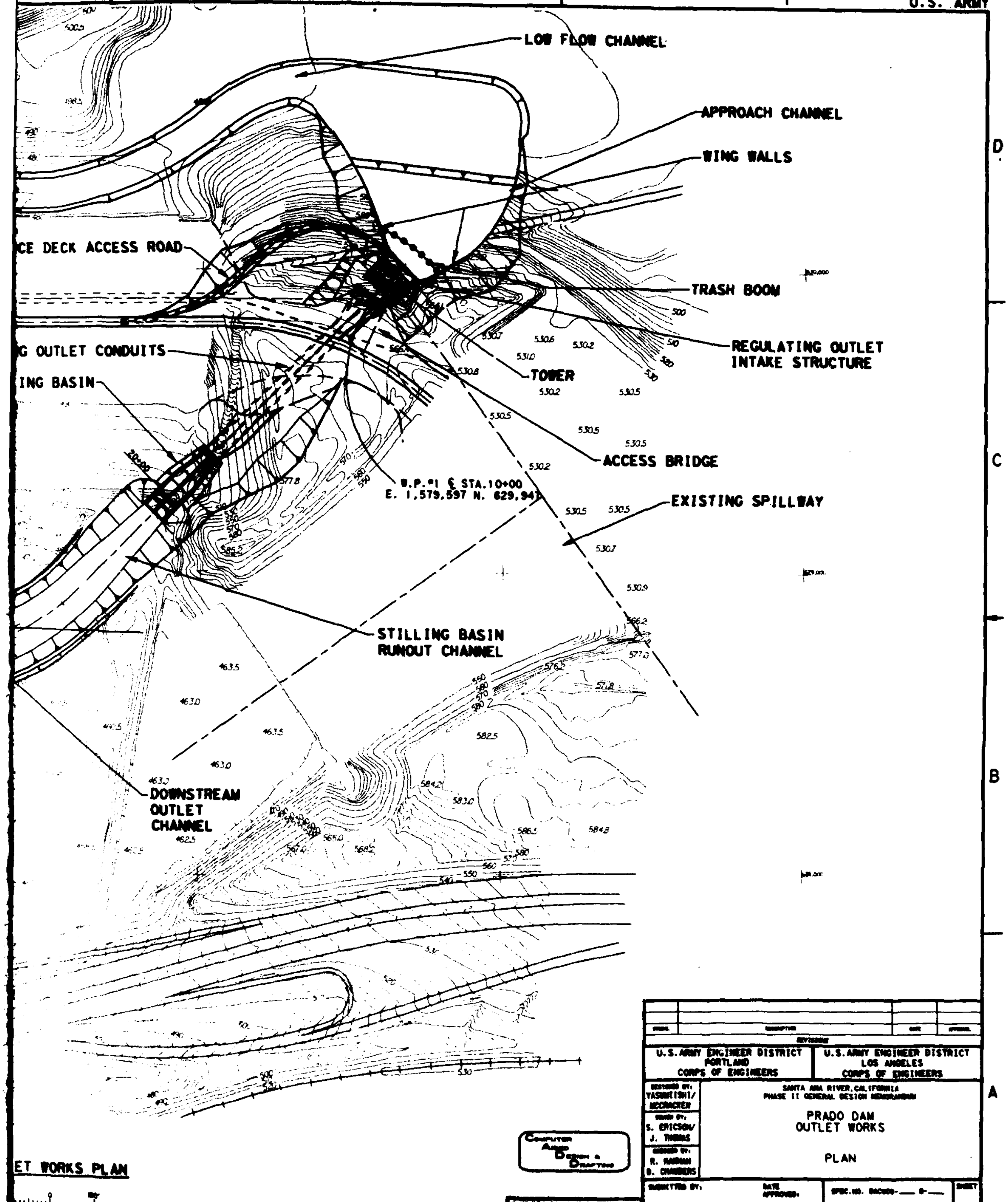
N
MAINTENANCE DECK ACCESS ROA
REGULATING OUTLET CONDUITS-
STILLING BASIN
EXISTING OUTLET CHANNEL TO BE BACKFILLED AND SLOPED TO DRAIN
EXISTING OUTLET CHANNEL TO REMAIN
FLOW
30+00
40+00
DO
OU
CH
EXISTING CORONA FREEWAY BRIDGE
EXISTING DROP STRUCTURE
RIVERSIDE FREEWAY
ROCK RIPRAP REVETMENT EXTENDS FROM STA. 20+00 TO STA. 49+00
OUTLET WORKS PLAN



ET WORKS PLAN

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
PORTLAND
CORPS OF ENGINEERS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
YASUMIISHI/
MCCRACKEN

DRAWN BY:
S. ERICSON/
J. THOMAS

CHECKED BY:
R. HARMAN
D. CHAMBERS

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS

PLAN

SUBMITTED BY:
NEAL R. HANSON, P.E.

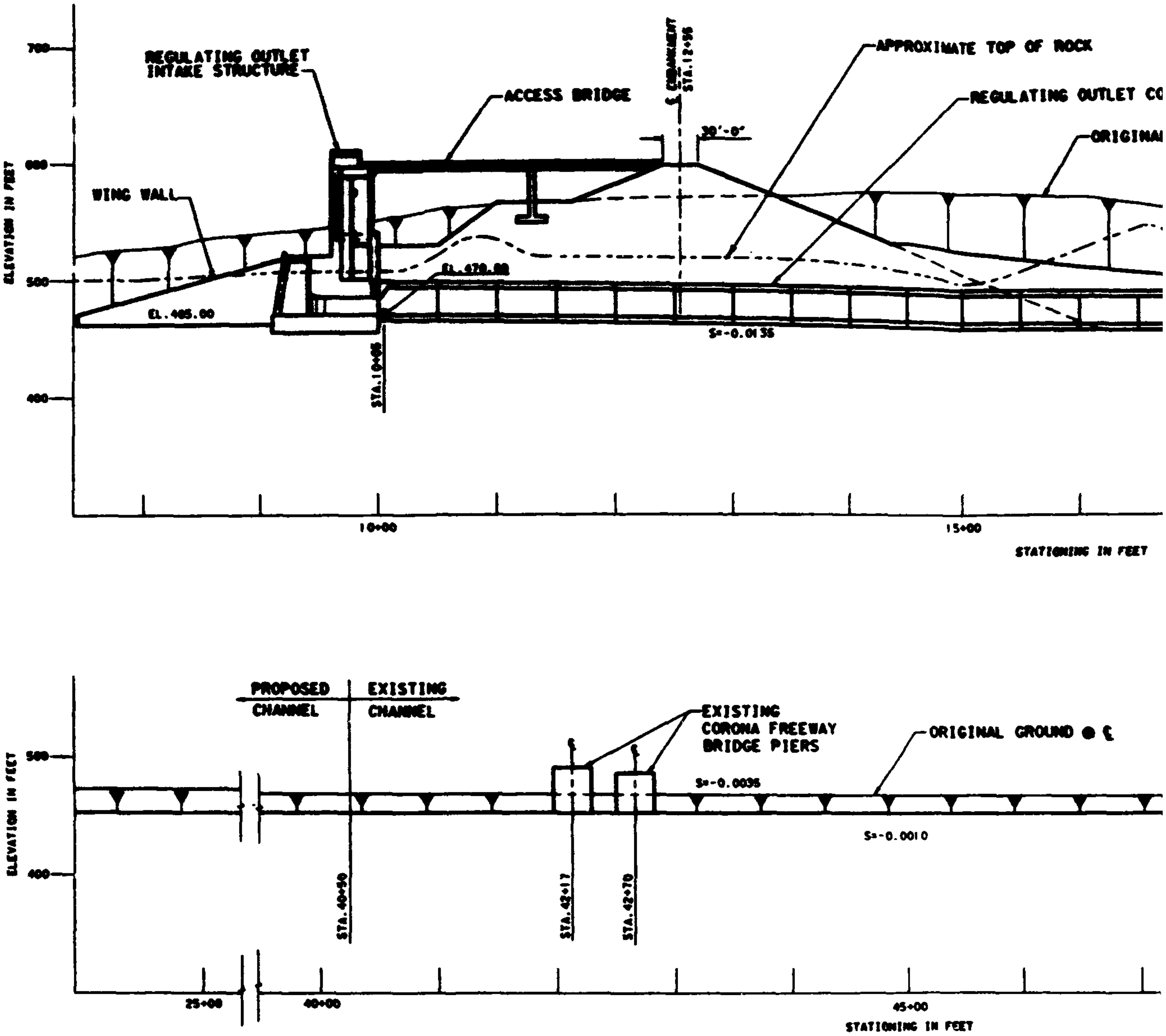
DATE APPROVED:
1988 JAN

SPEC. NO. DACW09-___ B-___

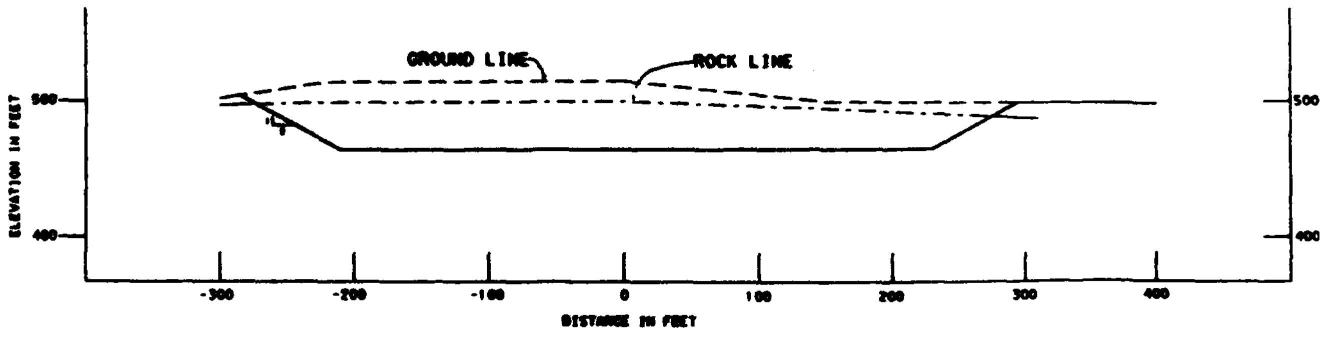
DISTRICT FILE NO. NPP-P-1

SHEET
1

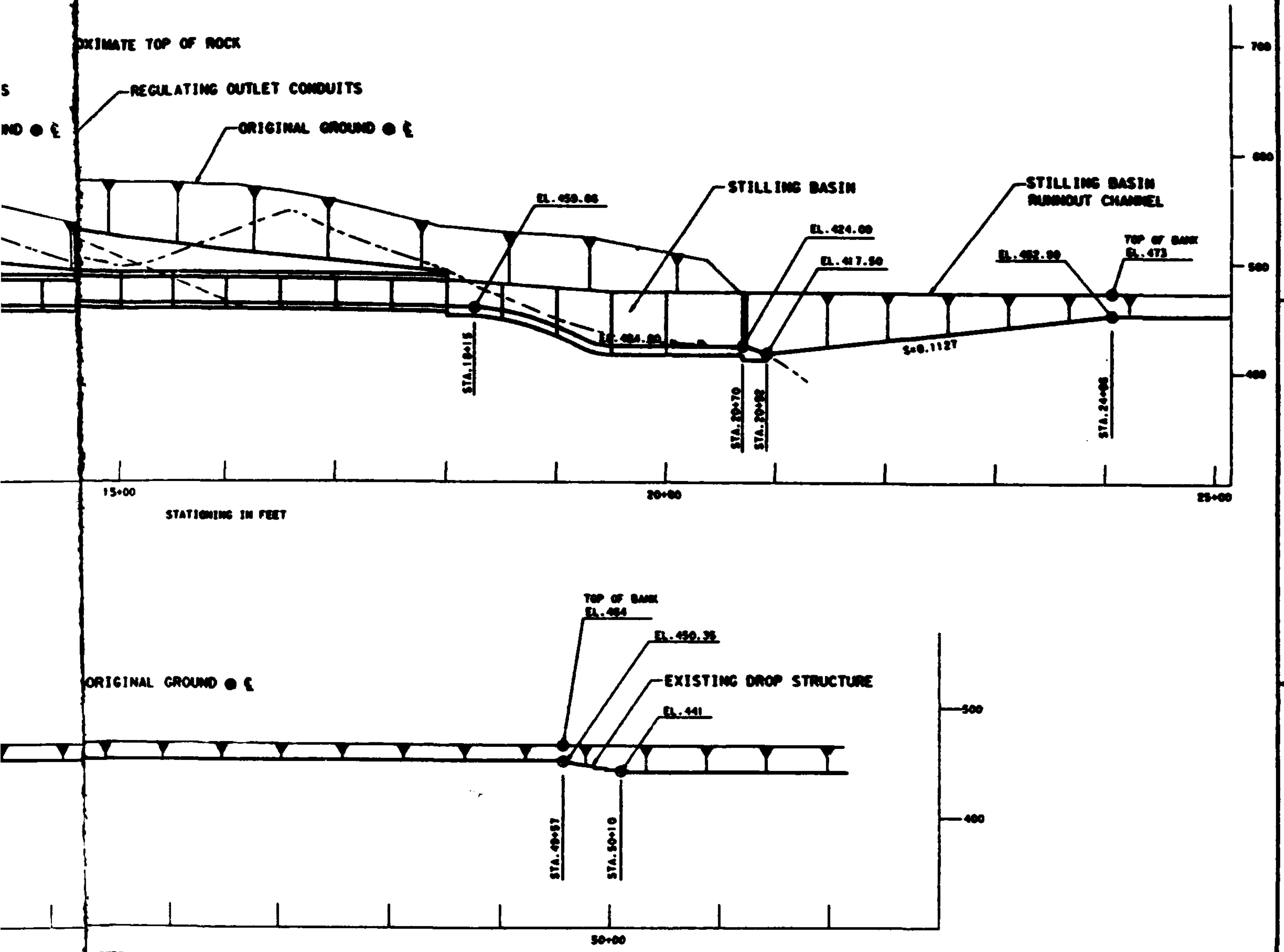
CADD DESIGN FILE:



OUTLET WORKS CENTERLINE PROFILE

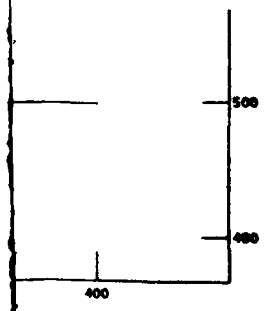


APPROACH CHANNEL



N FEET

LINE PROFILE



Computer Aided Design & Drafting

[illegible]	[illegible]	[illegible]	[illegible]

U.S. ARMY ENGINEER DISTRICT
PORTLAND
CORPS OF ENGINEERS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS

PROFILE

S. ERICSON/
J. [illegible]

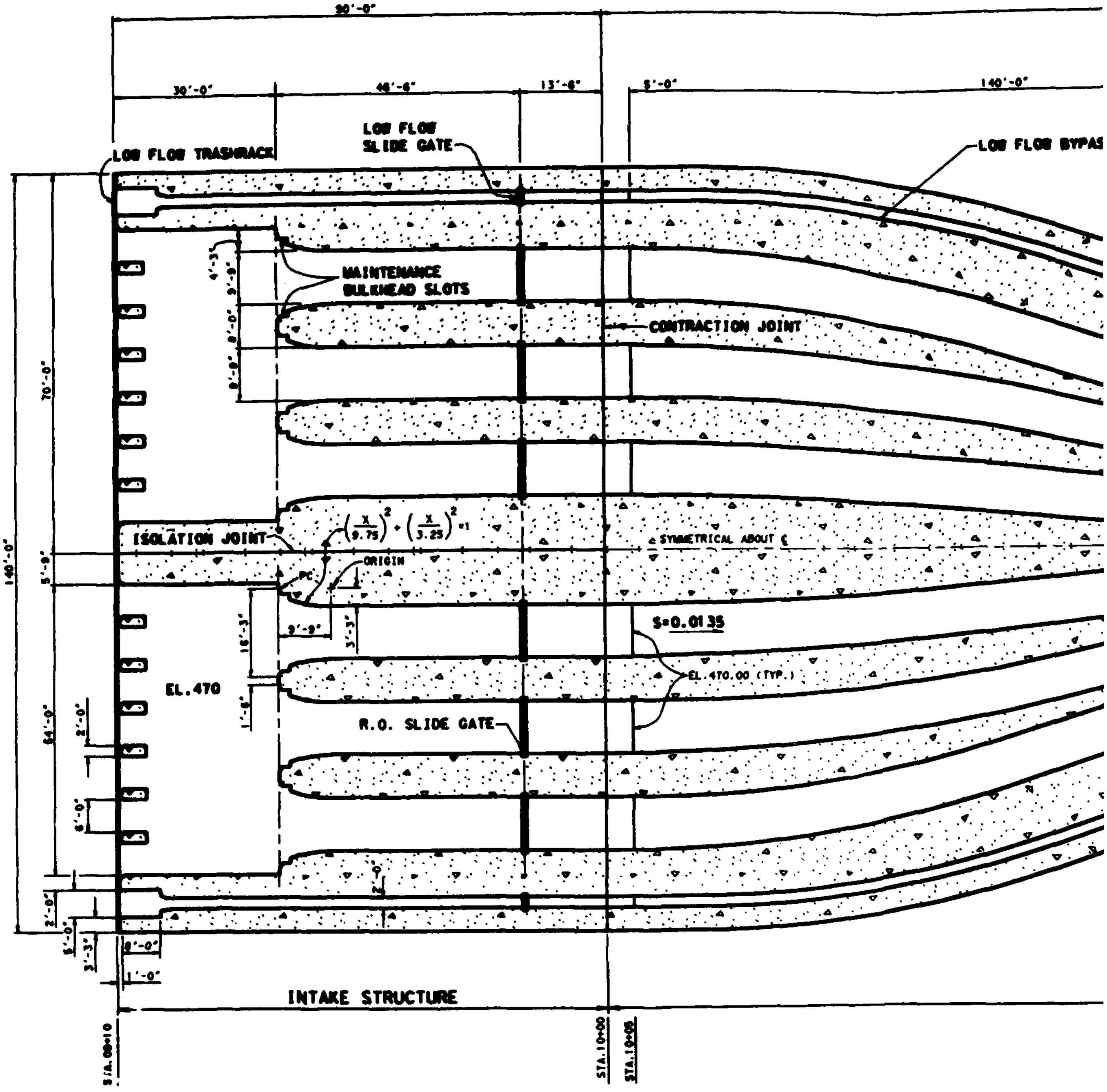
SUBMITTED BY:

DISTRICT FILE NO. [illegible]

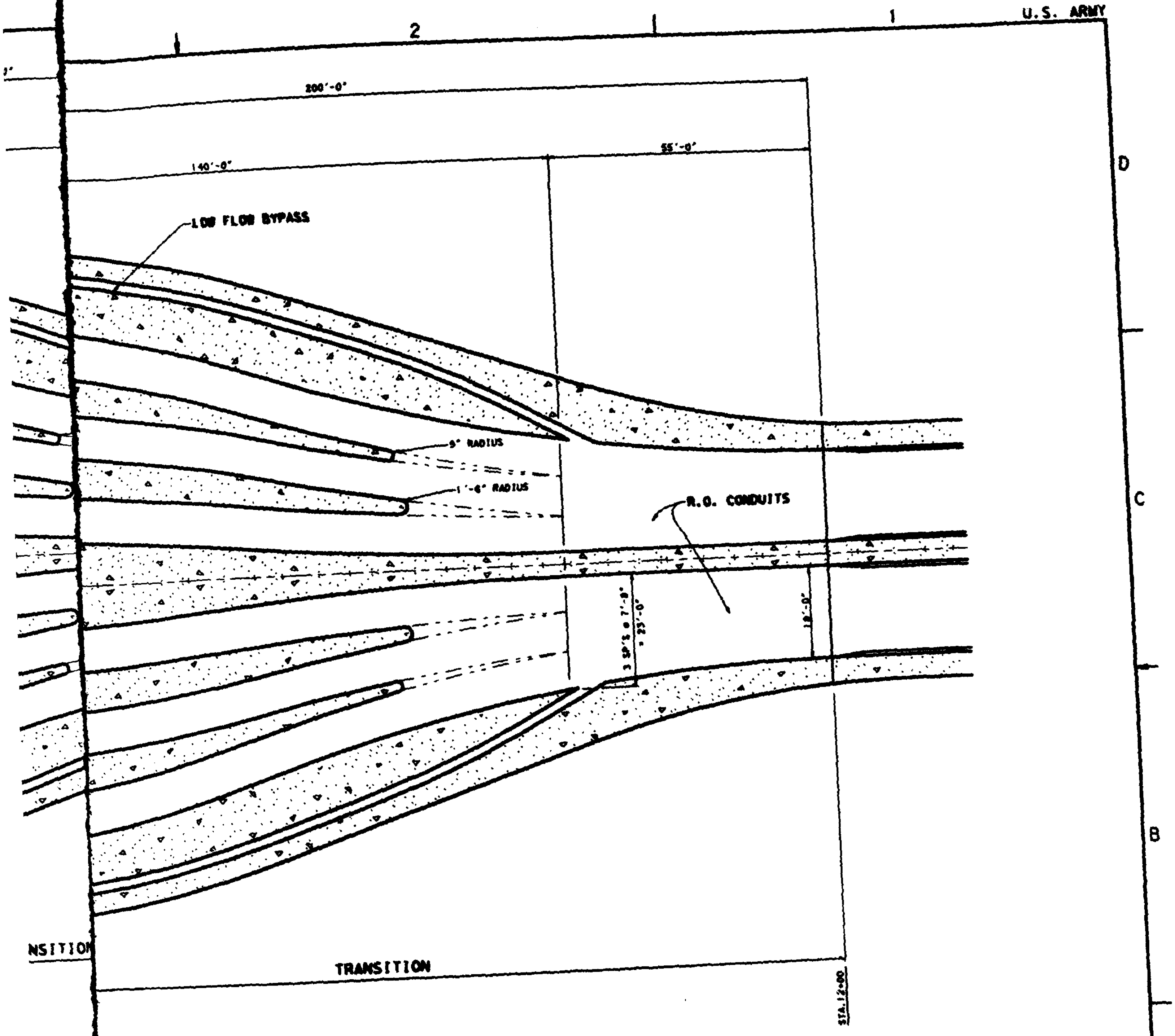
SHEET 2

A

CORPS OF ENGINEERS



INTAKE STRUCTURE AND TRANSITION PLAN - EL.470



REVISIONS

U.S. ARMY ENGINEER DISTRICT
PORTLAND
CORPS OF ENGINEERS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
REGULATING OUTLET
INTAKE STRUCTURE AND
TRANSITION PLAN - EL.470

DESIGNED BY: D. ILLIAS/ [illegible]
DRAWN BY: S. ERICSON/ J. THOMAS
CHECKED BY: B. CHAMBERS

COMPUTER AIDED DESIGN & DRAFTING

SUBMITTED BY:
DATE APPROVED: 1987 SEPT 30

SPEC. NO. DACW09-__ B-__
DISTRICT FILE NO. [illegible]
SHEET 3

PLATE C-3

A

1
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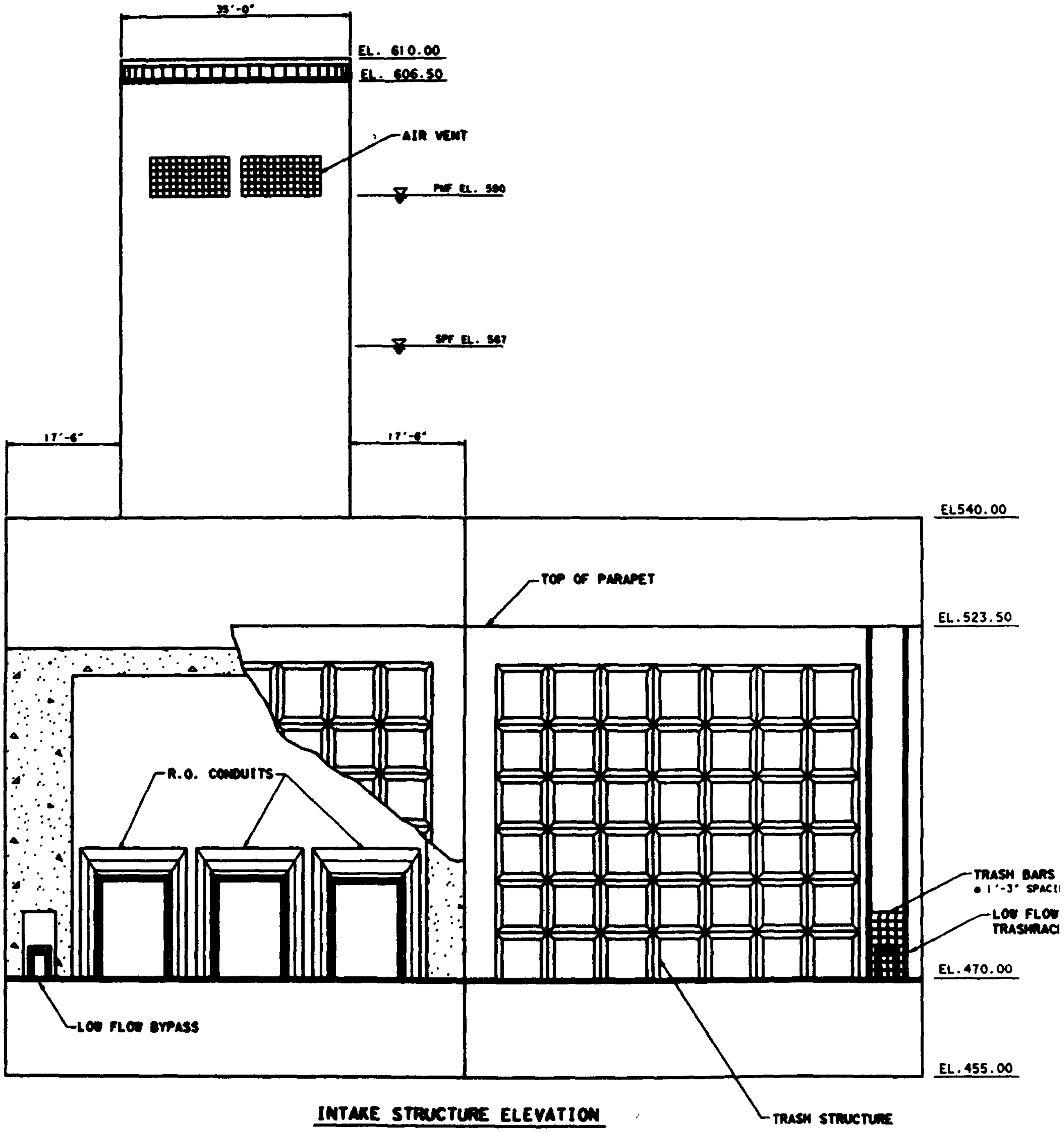
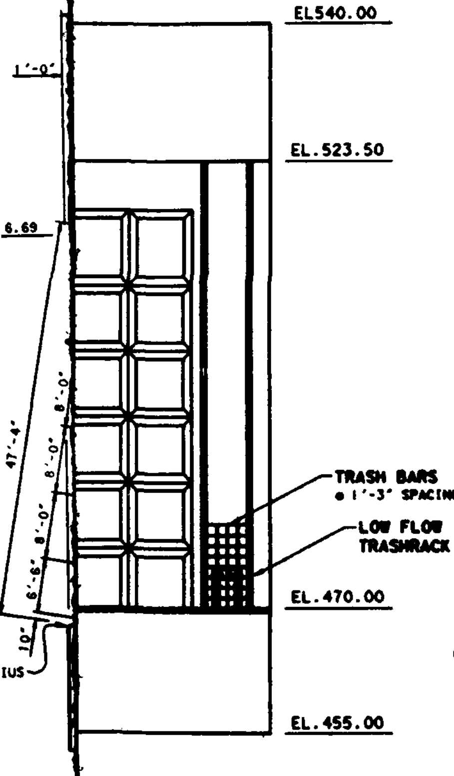
2

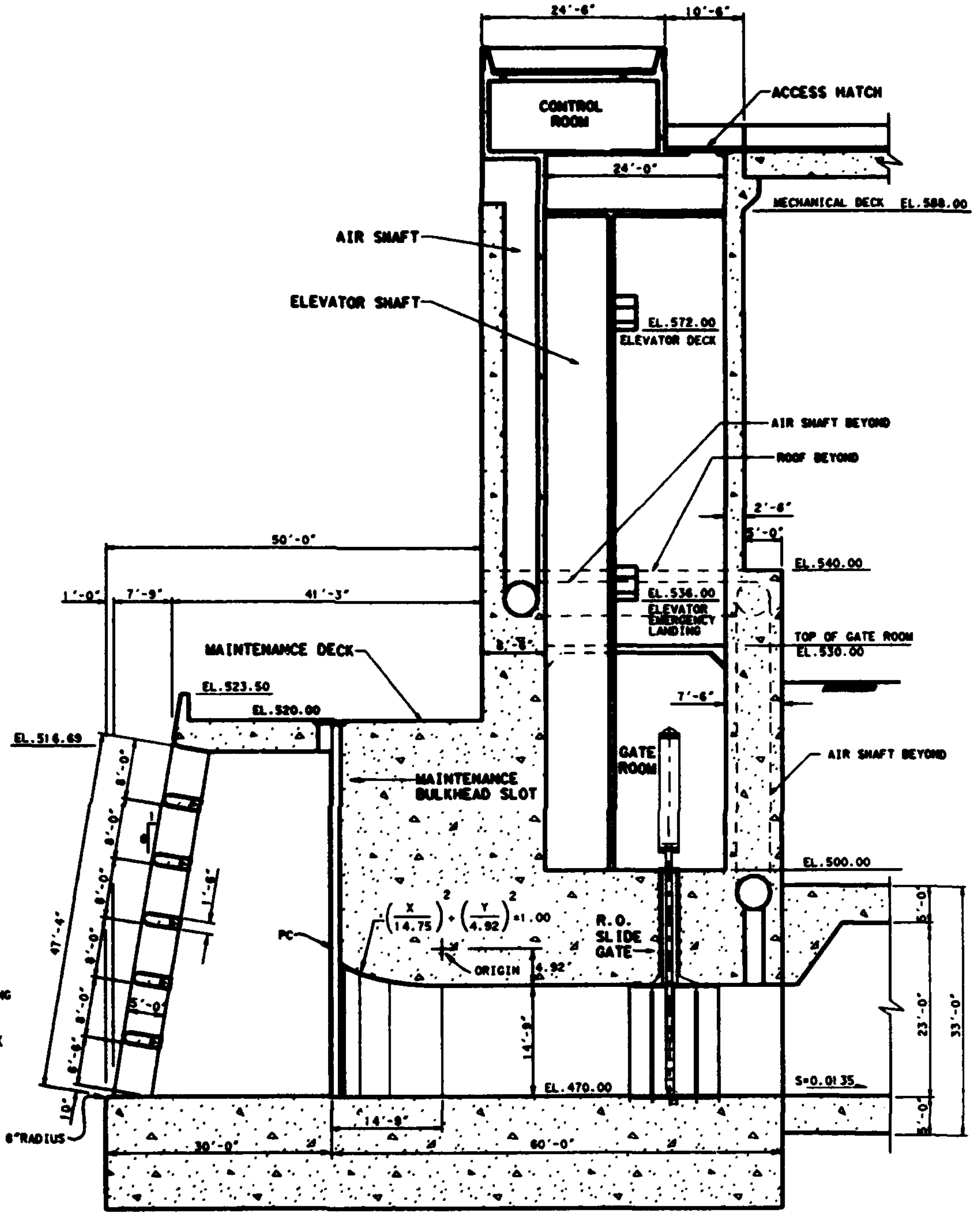
CORPS OF ENGINEERS



INTAKE STRUCTURE ELEVATION



TRASH STRUCTURE



INTAKE STRUCTURE SECTION

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT PORTLAND CORPS OF ENGINEERS	U.S. ARMY ENGINEER DISTRICT LOS ANGELES CORPS OF ENGINEERS

DESIGNED BY:
D. ALLIAS/
B. MCCRACKEN

DRAWN BY:
S. ERICSON/
J. THOMAS

CHECKED BY:
B. CHAMBERS

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
REGULATING OUTLET

INTAKE STRUCTURE ELEVATION
AND SECTION

SUBMITTED BY:
NEAL R. [illegible], P.E.

DATE APPROVED:
1987 SEPT 30

SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO.
 NPP-P-4

SHEET
4

Computer
Aided
Design &
Drafting

CADD DESIGN FILE:
[illegible]

PLATE C-4

2

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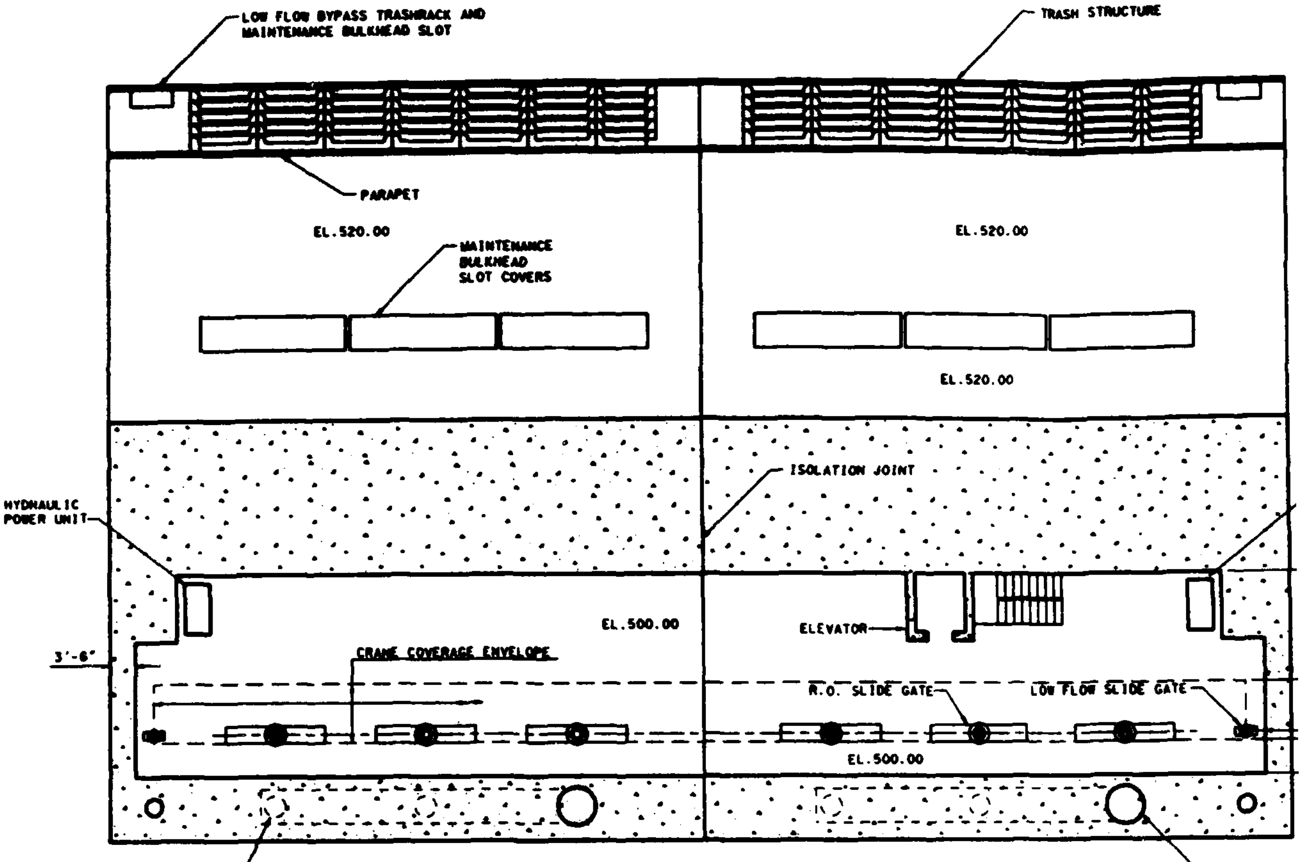
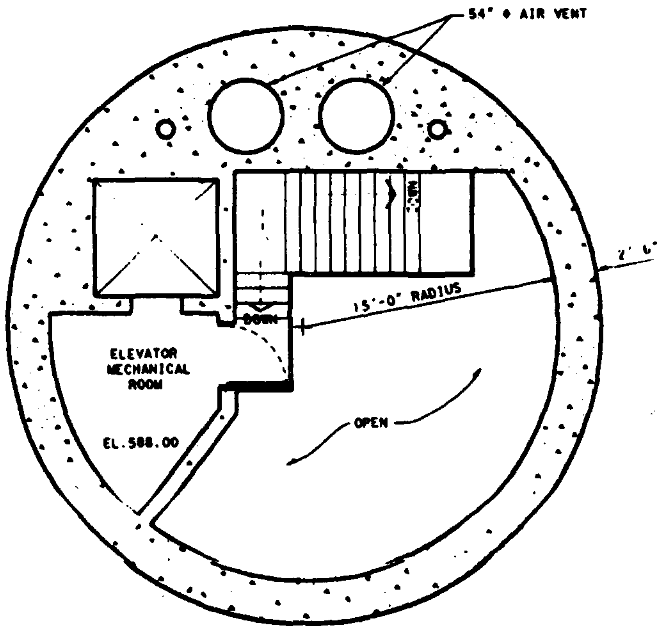
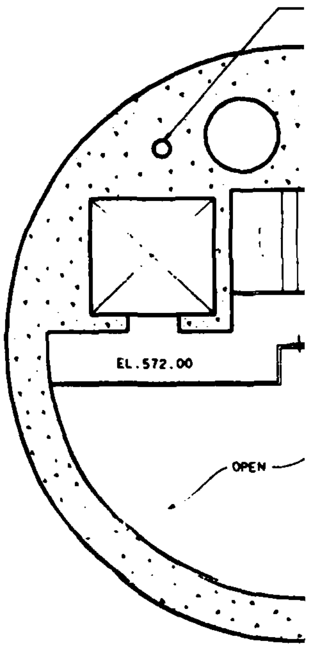


GATE ROOM AND MAINTENANCE DECK PLAN
EL.500 AND EL.520

B



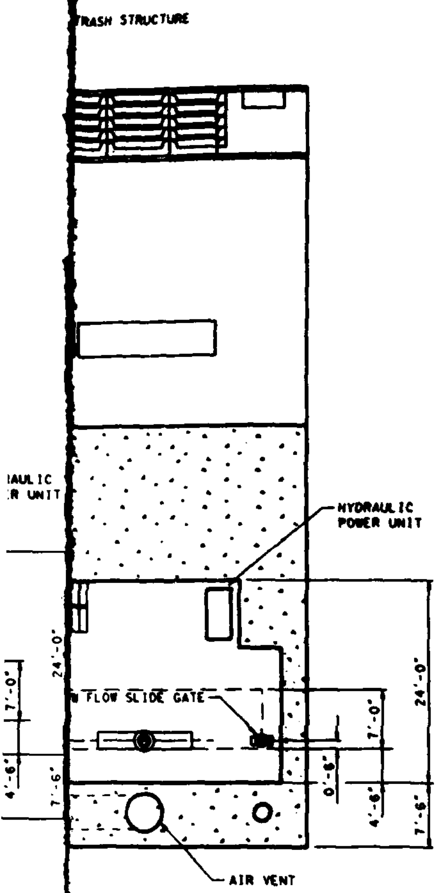


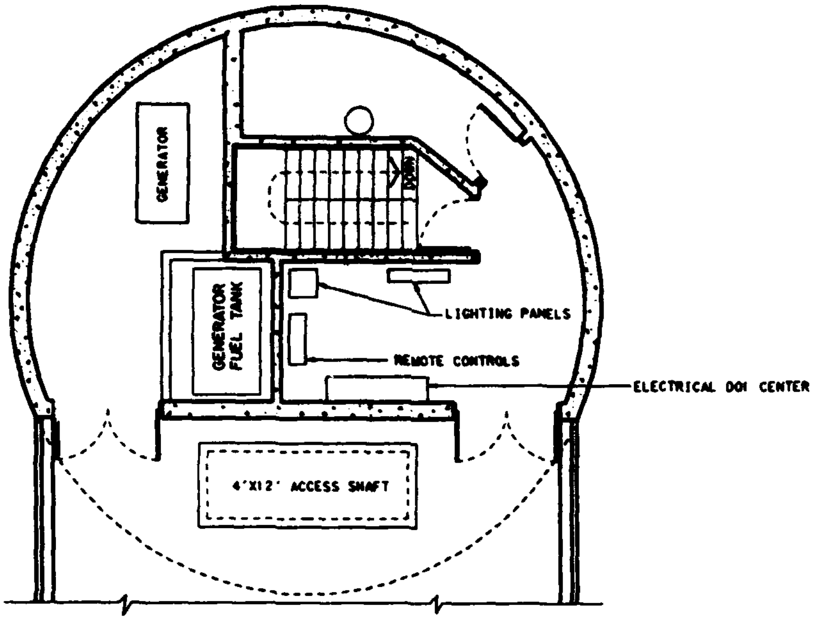
A

MECHANICAL DECK
EL.588

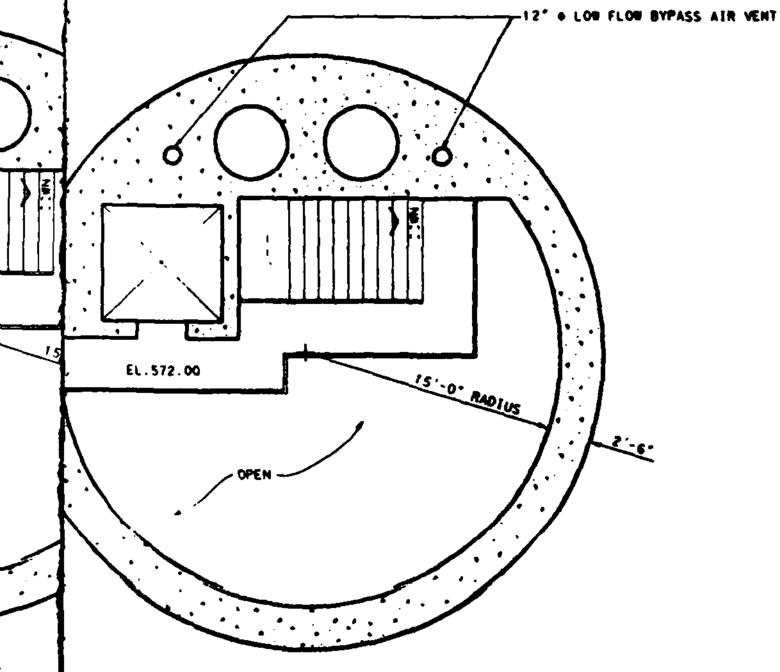
ELEVATO
EL.

U.S. ARMY





CONTROL ROOM PLAN
EL. 596



ELEVATOR DECK
EL. 572

NOTE: A FLOAT WELL SHALL BE INSTALLED TO ACCOMMODATE RESERVOIR SENSING EQUIPMENT.

COMPUTER AIDED DESIGN & DRAFTING

CADD DESIGN FILE: [illegible]

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT PORTLAND CORPS OF ENGINEERS	U.S. ARMY ENGINEER DISTRICT LOS ANGELES CORPS OF ENGINEERS

DESIGNED BY: D. ILLIAS/ B. McCRACKEN

DRAWN BY: S. ERICSON/ J. THOMAS

CHECKED BY: D. CHAMBERS

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
REGULATING OUTLET

INTAKE STRUCTURE PLANS

SUBMITTED BY: NEAL R. HANSON, P.E. CHIEF, DESIGN BRANCH

DATE APPROVED: 1987 SEPT 30

SPEC. NO. DACW09-___ B-___.

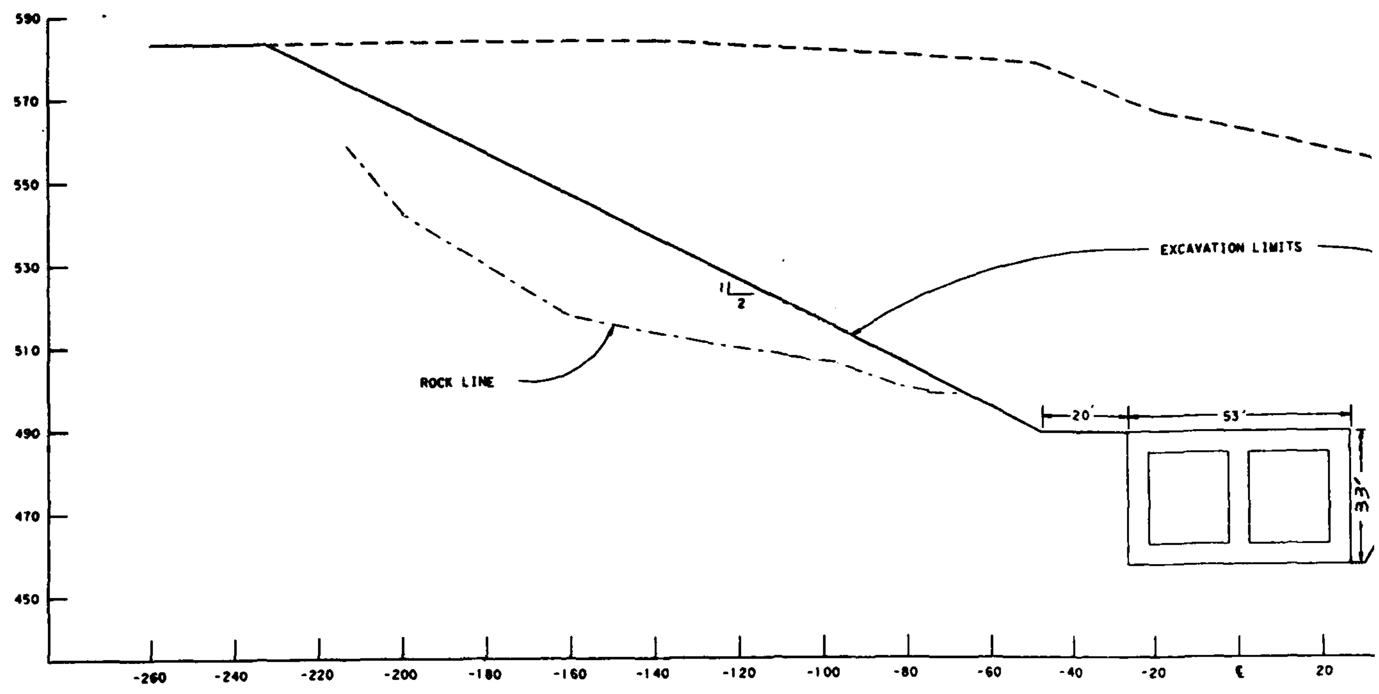
DISTRICT FILE NO. HPP-P-5

SHEET 5

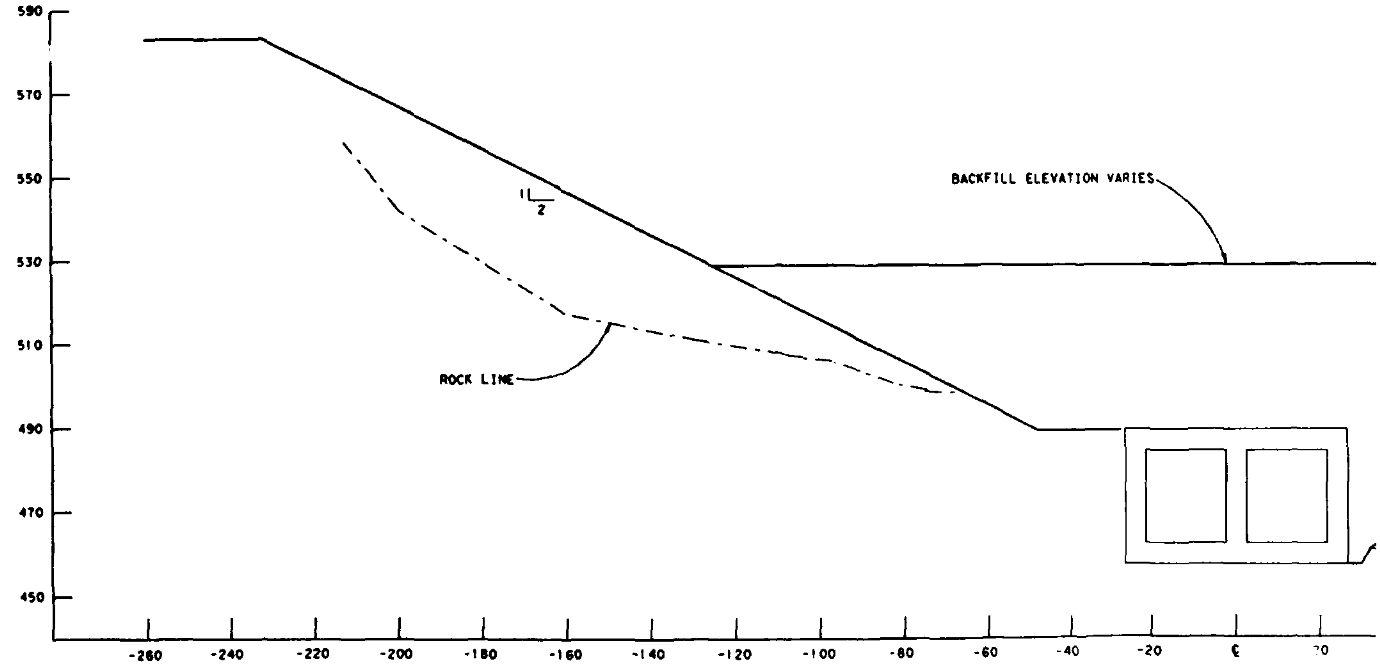
1 2

PLATE C-6

CORPS OF ENGINEERS 4 3



CONDUIT EXCAVATION



CONDUIT BACKFILL

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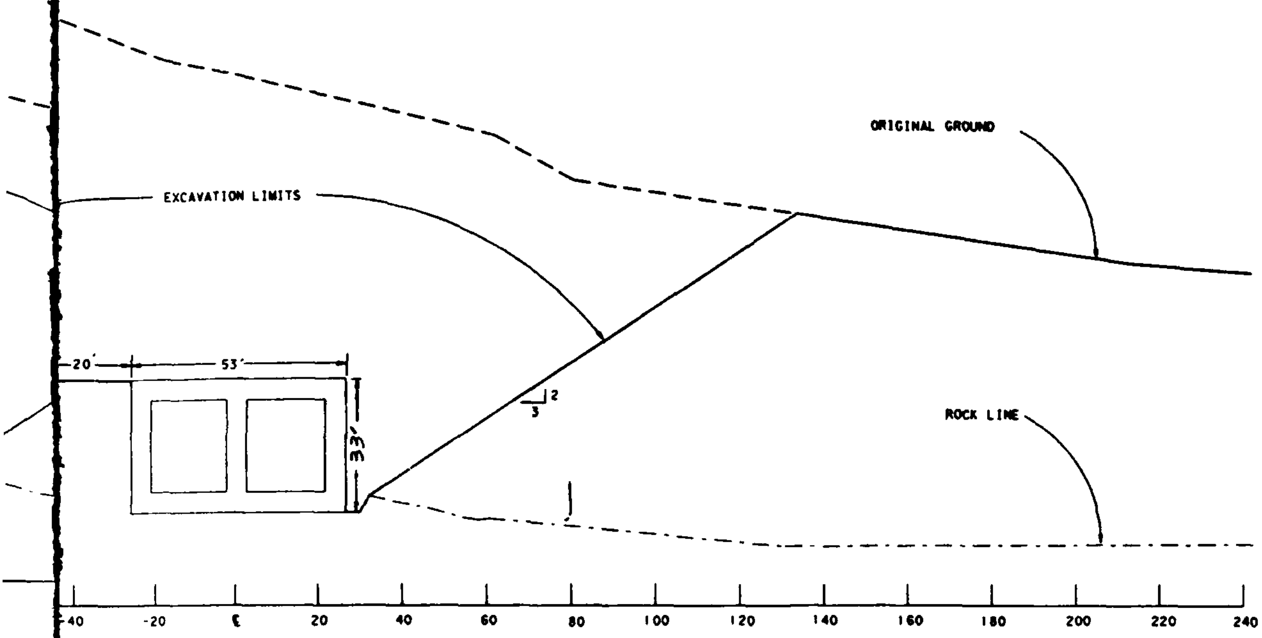
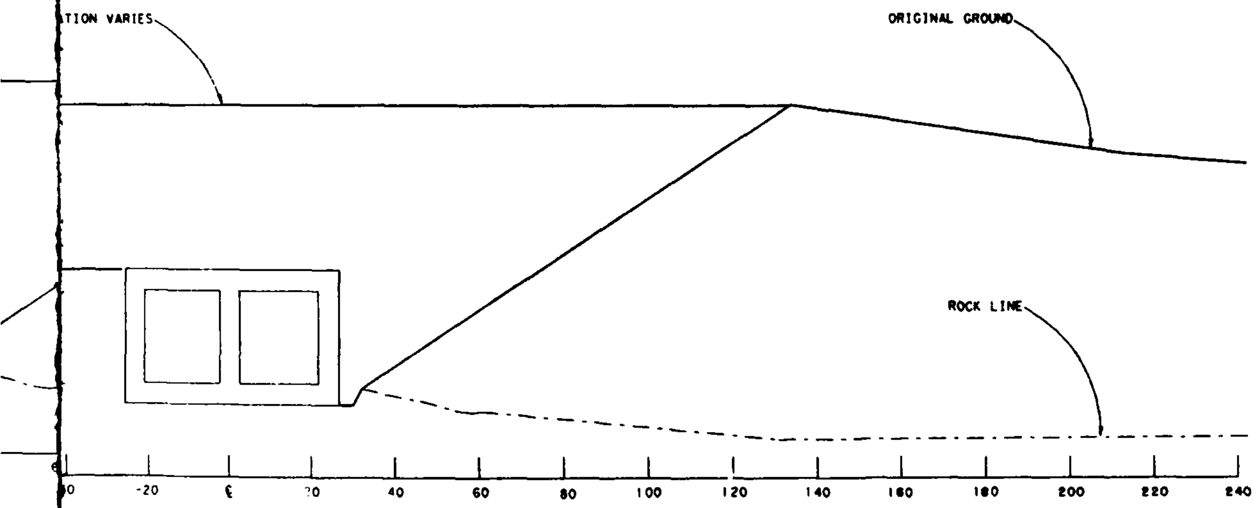


CONDUIT EXCAVATION (TYP.)



CONDUIT BACKFILL (TYP.)

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
PORTLAND
CORPS OF ENGINEERS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: KKY

DRAWN BY: KKY

CHECKED BY:

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
REGULATING OUTLET
EXCAVATION AND BACKFILL SECTION

CADD DESIGN FILE:
GEAI:[200,201]TYPICAL1.DGN

SUBMITTED BY:
STEVE L. STOCKTON, P.E.
CHIEF, GEOTECHNICAL BRANCH

DATE APPROVED: 1987 SEPT. 30

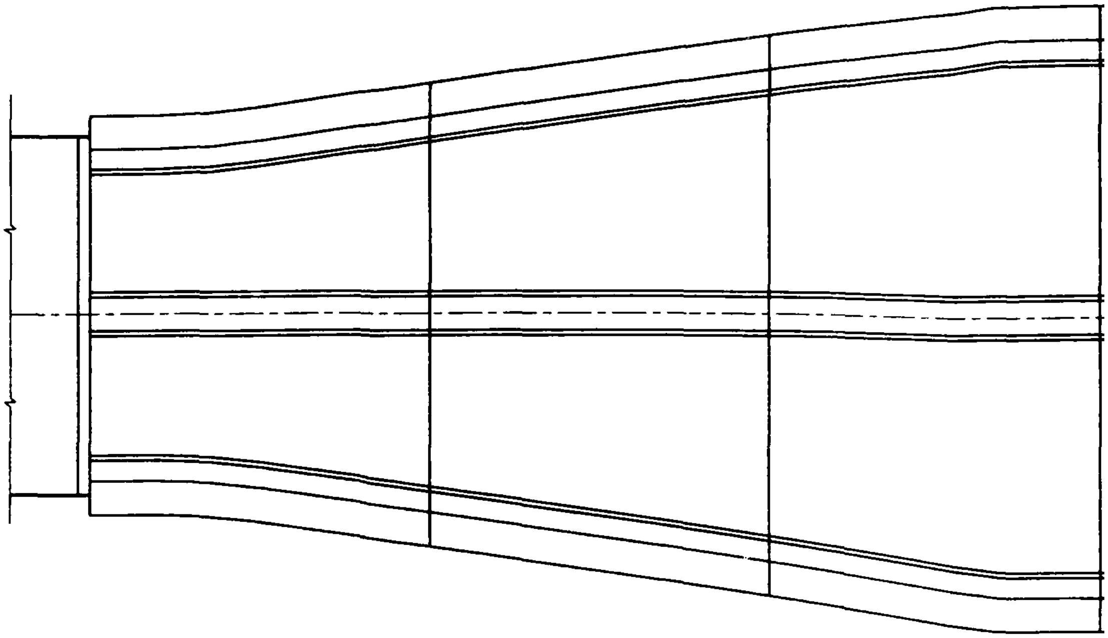
SPEC. NO. DACW09-___ B-___

DISTRICT FILE NO. HPP-P-6

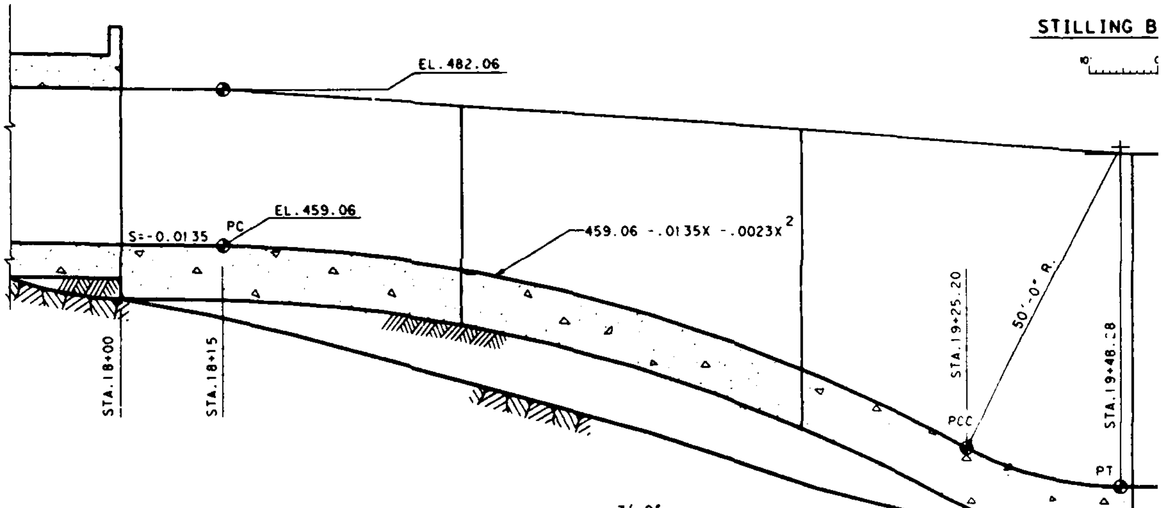
SHEET 6

PLATE C-6

3

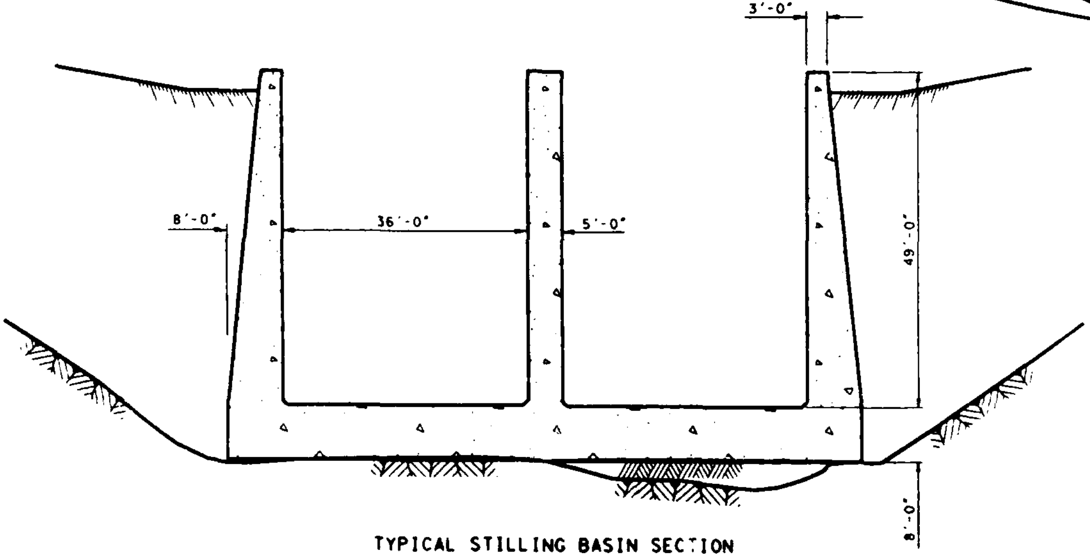


STILLING B



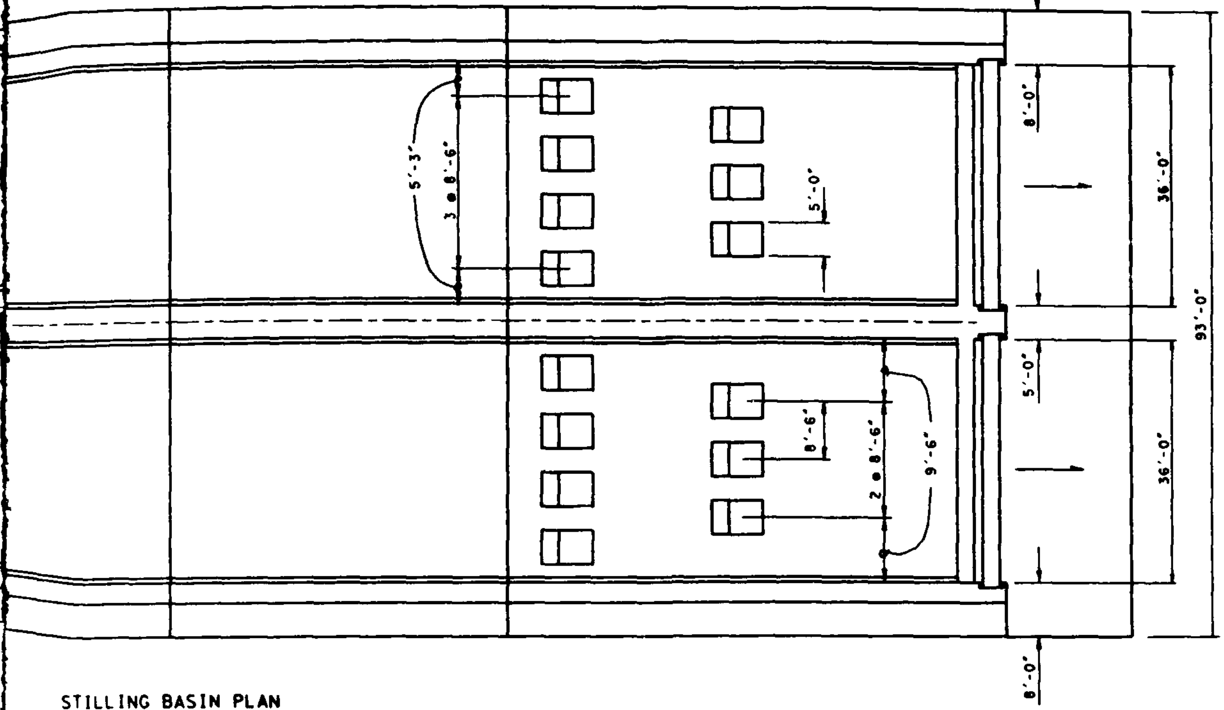
STILLING BASIN L

5'-0"

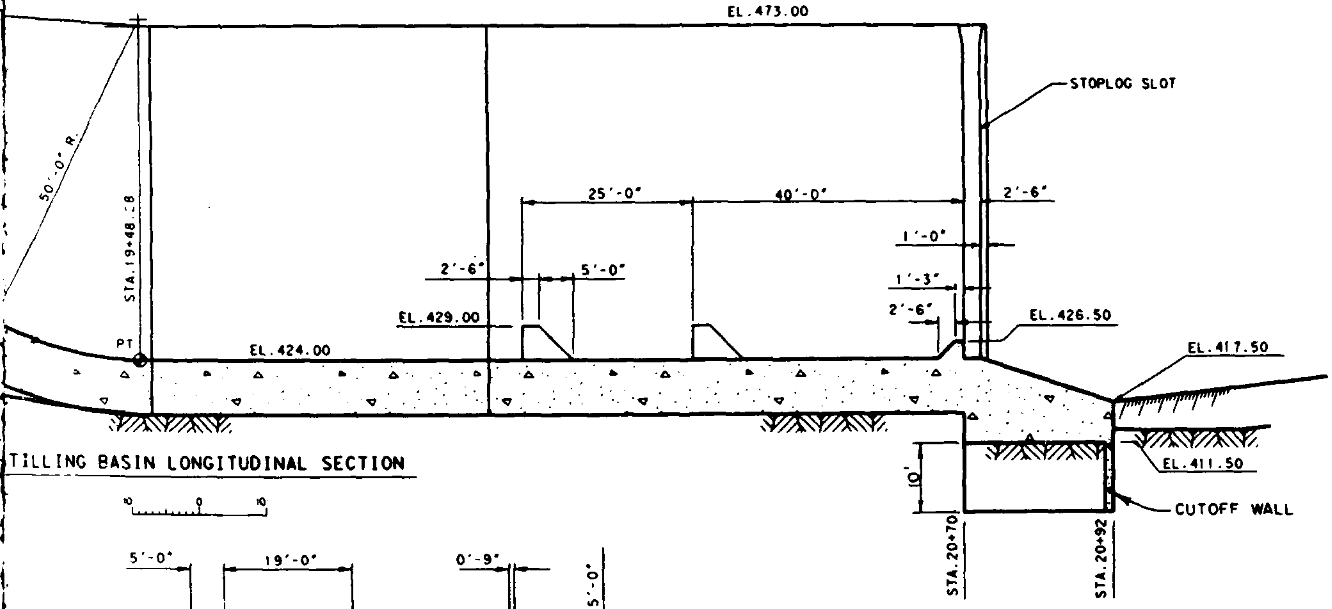


TYPICAL STILLING BASIN SECTION

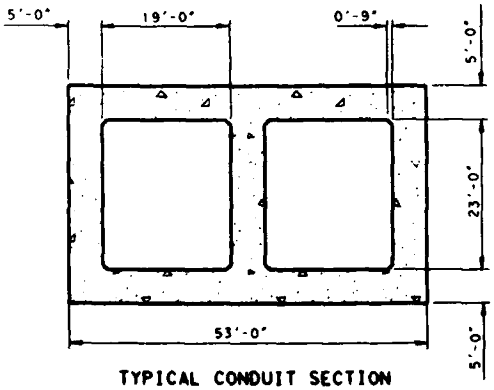
U.S. ARMY



STILLING BASIN PLAN



STILLING BASIN LONGITUDINAL SECTION



TYPICAL CONDUIT SECTION

Computer
Aided
Design &
Drafting

CADD DESIGN FILE:
[illegible] [PRD,201]PLATE7.DGN

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT PORTLAND CORPS OF ENGINEERS	U.S. ARMY ENGINEER DISTRICT LOS ANGELES CORPS OF ENGINEERS

DESIGNED BY:
D. ILLIAS/
B. McCRACKEN

DRAWN BY:
S. ERICSON/
J. THOMAS

CHECKED BY:
D. CHAMBERS

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
STILLING BASIN

PLAN AND SECTIONS

SUBMITTED BY:
NEAL R. HANSON, P.E.
CHIEF, DESIGN BRANCH

DATE APPROVED:
1987 SEPT 30

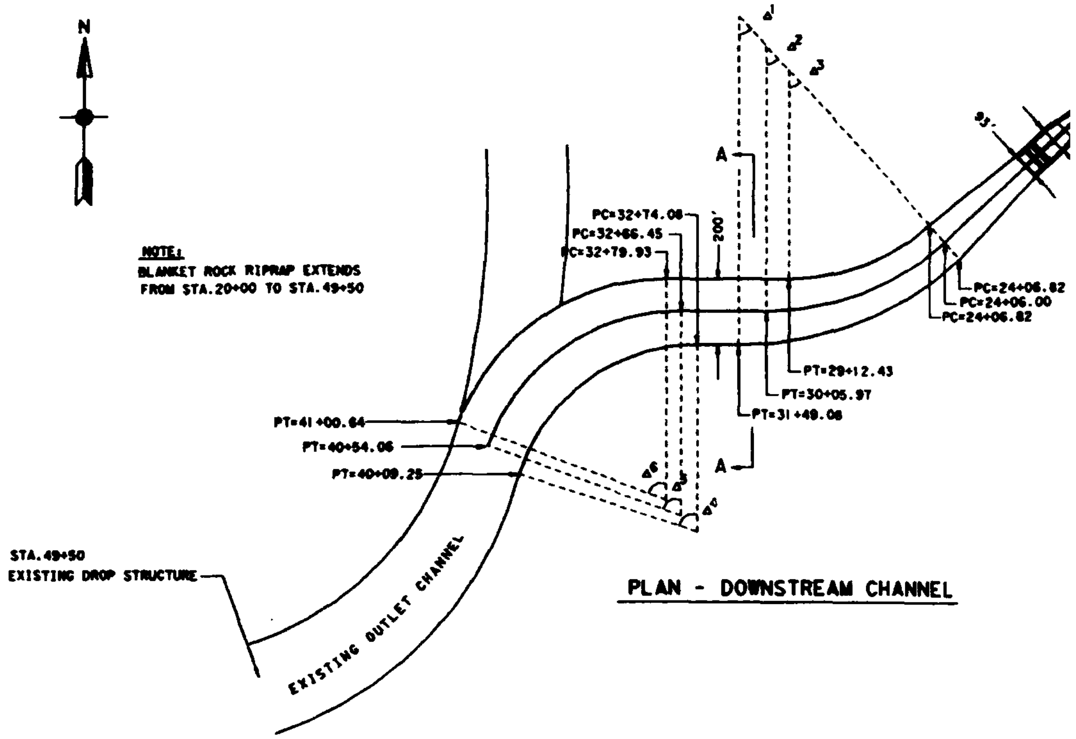
SPEC. NO. DACW09-____ B-____
DISTRICT FILE NO. WPP-P-7

SHEET
7

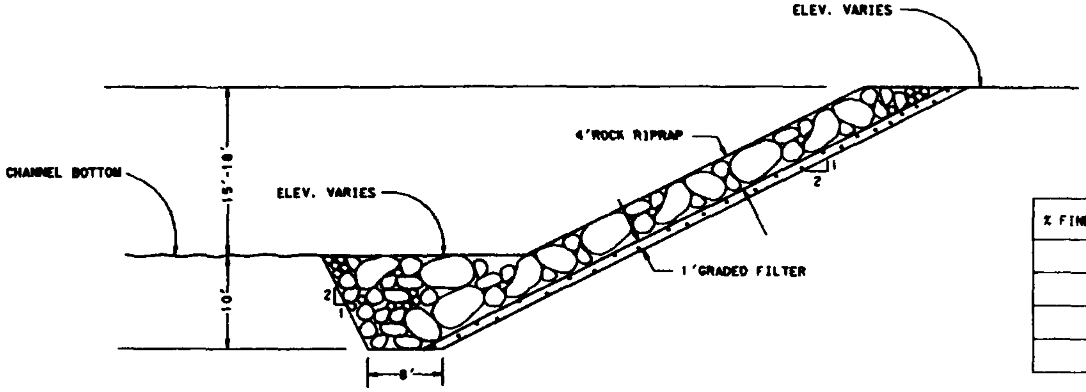
PLATE C-7

9

NOTE:
BLANKET ROCK RIPRAP EXTENDS
FROM STA.20+00 TO STA.49+50



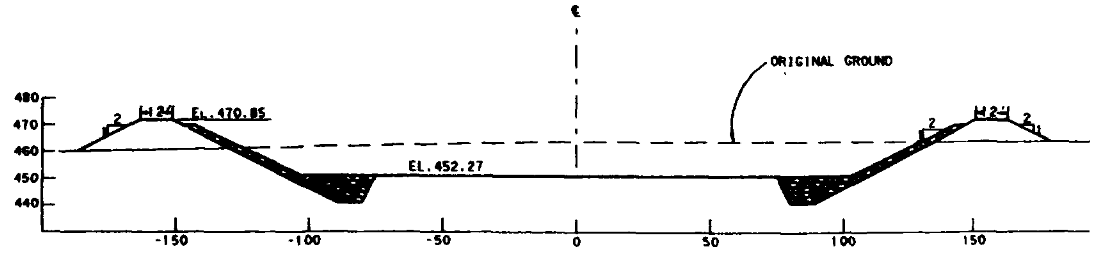
PLAN - DOWNSTREAM CHANNEL



RIPRAP

RIP

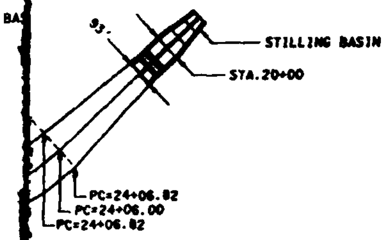
% FINER (BY WEIGHT)
100
50
25
15



SECTION A

STA. 30+20

— STILLING BA
TA.20+00



NEL

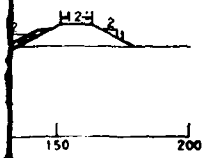
CURVE	POINT	STATION	NORTH	EAST	CURVE INFORMATION
NORTH - U.S.	PC	24+06.82	629,002.31	1,578,553.31	L = 505.61 FT. R = 630.00 FT. T = 267.30 D = 08°05'40" Δ = 45°58'56"
	PI		629,447.79	1,578,107.83	
	PT	29+12.43	628,817.88	1,578,007.03	
NORTH - D.S.	PC	32+79.93	628,824.18	1,577,729.58	L = 820.71 FT. R = 580.00 FT. T = 496.02 FT. D = 08°52'43" Δ = 81°04'27"
	PI		628,244.27	1,577,719.64	
	PT	41+00.64	628,342.00	1,577,150.00	
CENTERLINE - U.S.	PC	24+06.00	628,952.81	1,578,602.81	L = 599.97 FT. R = 800.00 FT. T = 314.88 FT. D = 07°09'43" Δ = 42°58'09"
	PI		629,518.50	1,578,037.13	
	PT	30+05.97	628,719.00	1,578,065.48	
CENTERLINE - D.S.	PC	32+66.45	628,720.00	1,577,805.00	L = 787.61 FT. R = 582.00 FT. T = 467.41 FT. D = 09°50'41" Δ = 77°32'14"
	PI		628,709.77	1,577,805.16	
	PT	40+54.06	628,267.00	1,577,234.00	
SOUTH - U.S.	PC	24+06.82	628,903.31	1,578,652.31	L = 742.26 FT. R = 990.00 FT. T = 389.55 FT. D = 05°47'15" Δ = 42°57'29"
	PI		629,603.35	1,577,952.27	
	PT	31+49.08	628,613.98	1,577,987.55	
SOUTH - D.S.	PC	32+74.08	628,609.53	1,577,862.63	L = 736.17 FT. R = 590.00 FT. T = 423.91 FT. D = 09°42'40" Δ = 71°23'36"
	PI		628,188.12	1,577,318.14	
	PT	40+09.25	628,187.00	1,577,319.00	

RADATION

IA.(IN)	STO
-33	
-26	
-14	
-10	

RIPRAP GRADATION

NER (BY WEIGHT)	STONE DIA.(IN)	STONE WEIGHT (LBS.)
100	44-33	4405-1762
50	30-26	1352-881
25	24-14	692-137
15	16-10	205-50



U.S. ARMY ENGINEER DISTRICT
PORTLAND
CORPS OF ENGINEERS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

KKY

P.LU

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS

DOWNSTREAM CHANNEL CROSS SECTION

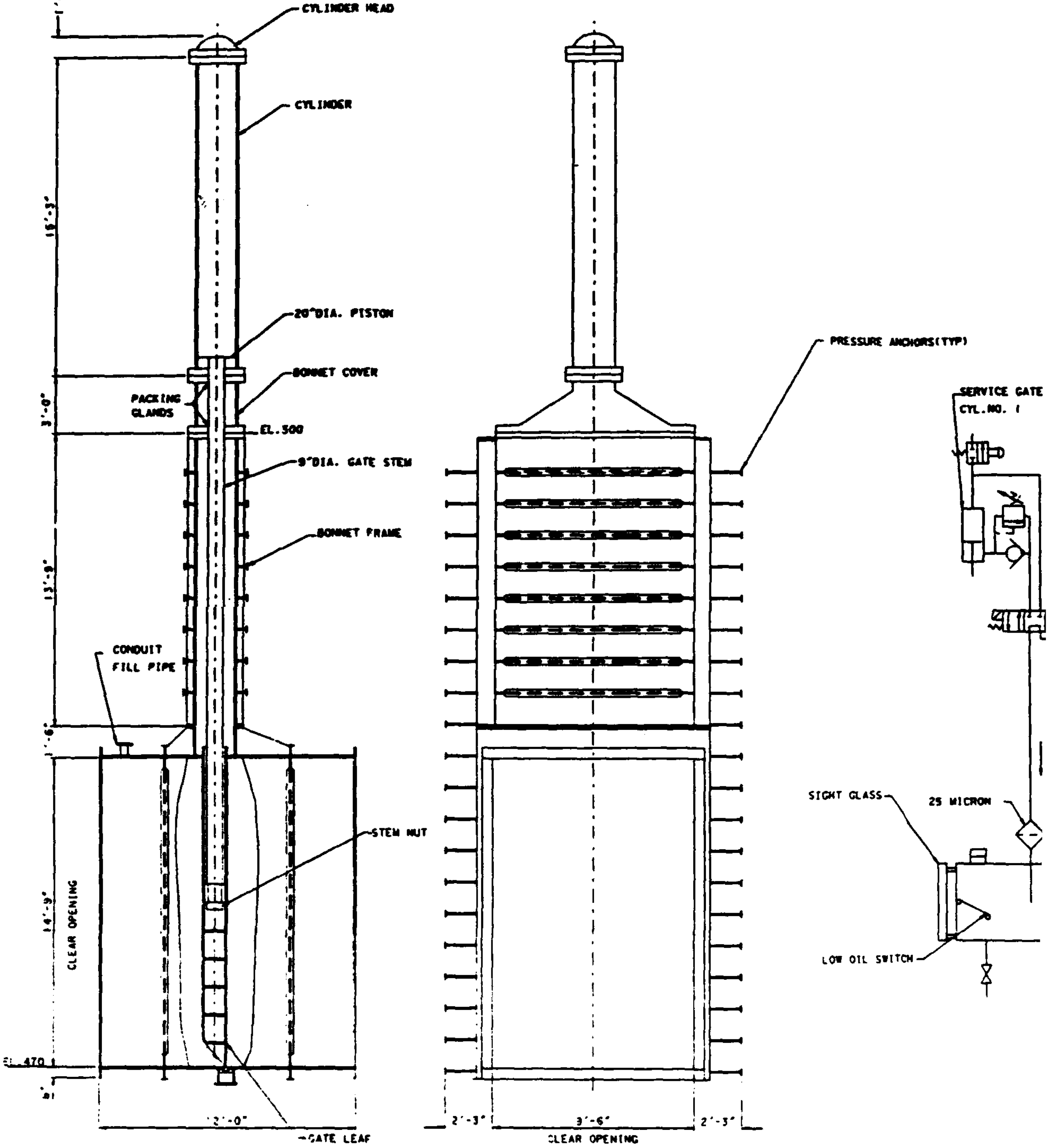
STEVEN L. STOCKTON, P.E. 1997 SEPT 30

SPEC. NO. DACW09-___ B-___

DISTRICT FILE NO.

CADD DESIGN FILE:
[illegible]

CORPS OF ENGINEERS

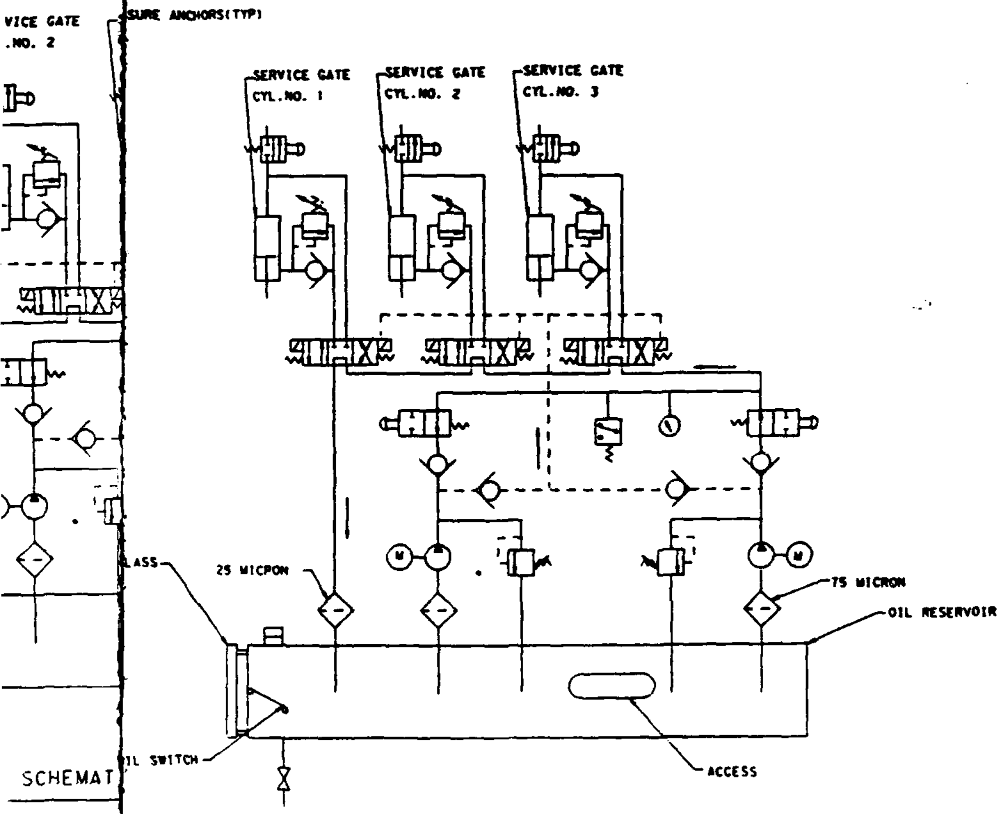


SIDE ELEVATION

FRONT ELEVATION

REGULATING OUTLET GATE

ITEM	NAME	DESCRIPTION
◇	OIL FILTER INDICATING TYPE	
●	INDUCTION MOTOR,1800RPM	25 HP, 460V, 3 PHASE
⊖	OIL PUMP 1800RPM	7.5-7.8 GPM, 1750 RPM, 2000 PSI
	PRESSURE RELIEF VALVE	1500-2500 PSI RANGE
	CYLINDER	DOUBLE ACTING
	CHECK VALVE	75 PSI CRACKING PRESSURE
	SHUT OFF VALVE	BALL OR GLOBE TYPE
⊘	4 INCH PRESSURE GAGE	0-3000 PSI
	PRESSURE SWITCH	1500-2500 PSI RANGE
	FILTER AND BREATHER CAP	COMMERCIAL
	FOUR WAY VALVE	SPR. CT.OP.CT. CYL.PORTS BLOCKED
	COUNTERBALANCE VALVE	200-500 PSI RANGE
	AIR BLEED VALVE	
⋈	GLOBE VALVE	



SCHEMATIC DIAGRAM

NO SCALE

NOTES:

1. ALL SIX GATES ARE IDENTICAL
2. SCHEMATIC IS TYPICAL FOR GATES 4,5,6

REVISIONS

U.S.ARMY ENGINEER DISTRICT PORTLAND CORPS OF ENGINEERS	U.S.ARMY ENGINEER DISTRICT LOS ANGELES CORPS OF ENGINEERS

DESIGNED BY: KST

DRAWN BY: DAB

CHECKED BY: RAM

SANTA ANA RIVER,CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
REGULATING OUTLET
RO GATE AND SCHEMATIC

SUBMITTED BY: NEAL R. HANSON, P.E.
CHIEF, DESIGN BRANCH

DATE APPROVED: 87 SEP.30

SPEC.NO. DACW09-__ B-__.

DISTRICT FILE NO. NPP-P-9

SHEE 9

Computer
Aided
Design &
Drafting

CADD DESIGN FILE:
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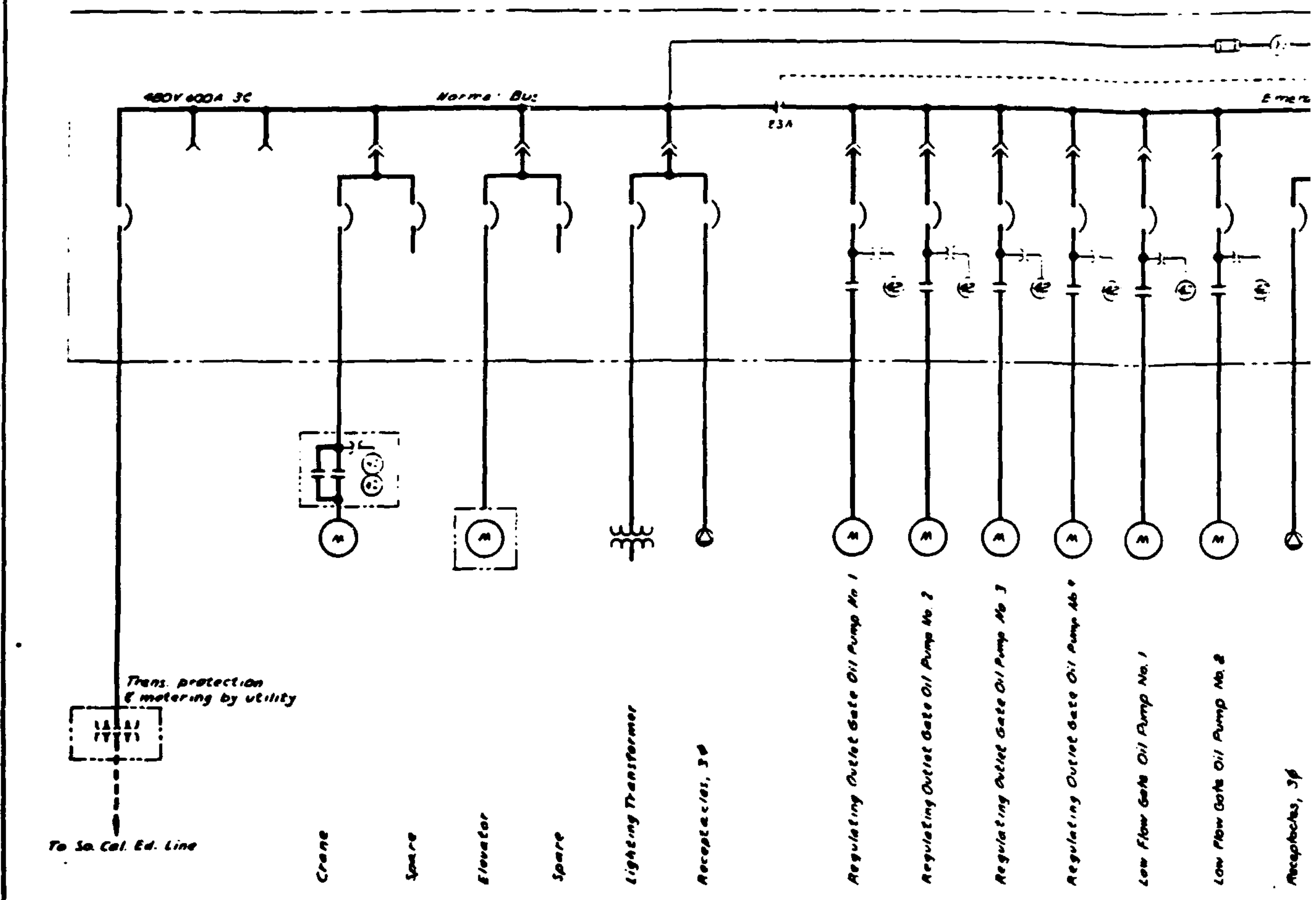
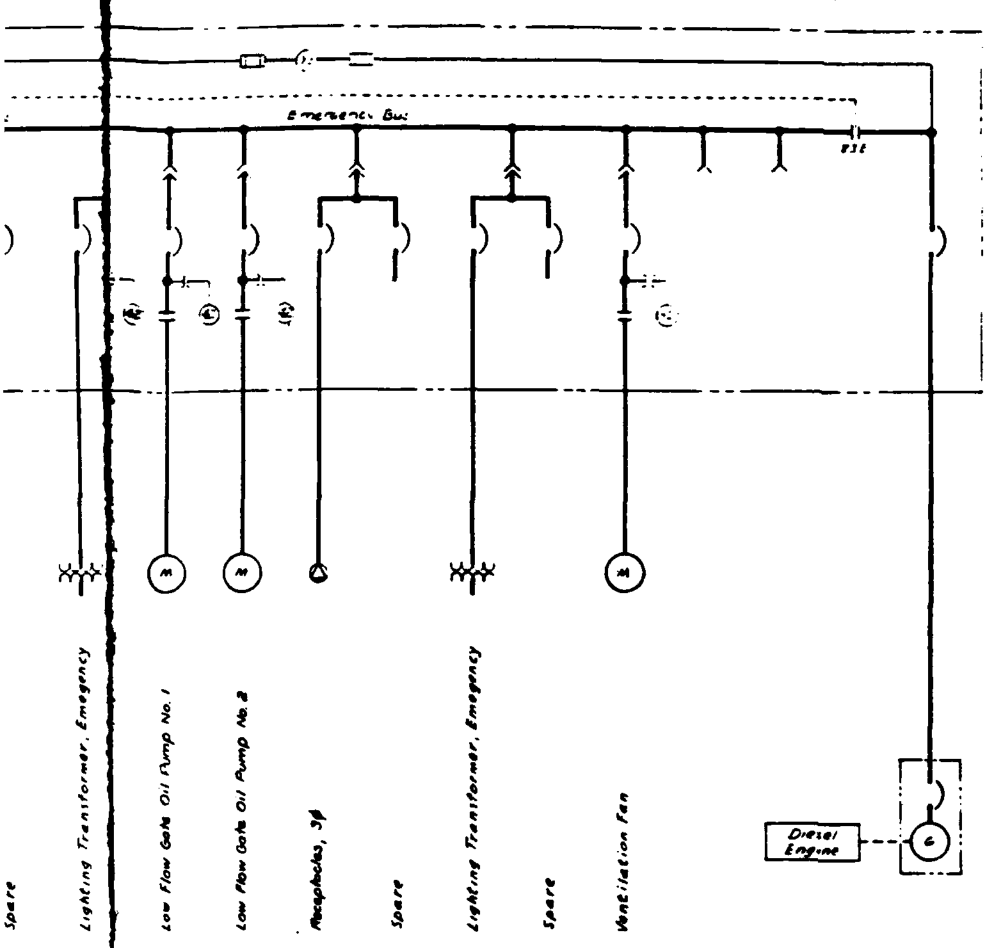

480V 400A 3C
Normal Bus
E3A
Emer
D
C
Trans. protection
& metering by utility
To So. Cal. Ed. Line
Crane
Spare
Elevator
Spare
Lighting Transformer
Receptacles, 3φ
Regulating Outlet Gate Oil Pump No. 1
Regulating Outlet Gate Oil Pump No. 2
Regulating Outlet Gate Oil Pump No. 3
Regulating Outlet Gate Oil Pump No. 4
Low Flow Gate Oil Pump No. 1
Low Flow Gate Oil Pump No. 2
Receptacles, 3φ
M
B
A
4
3



LEGEND

Ⓖ Generator

Ⓜ Motor

Receptacle 3φ 480V

Circuit Breaker or Motor Circuit Protector

Motor Starter

83 Auto-transfer Switch
E - Emergency
N - Normal

SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
PORTLAND
CORPS OF ENGINEERS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: RTO
DRAWN BY: MAK
CHECKED BY: JP

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
ELECTRICAL

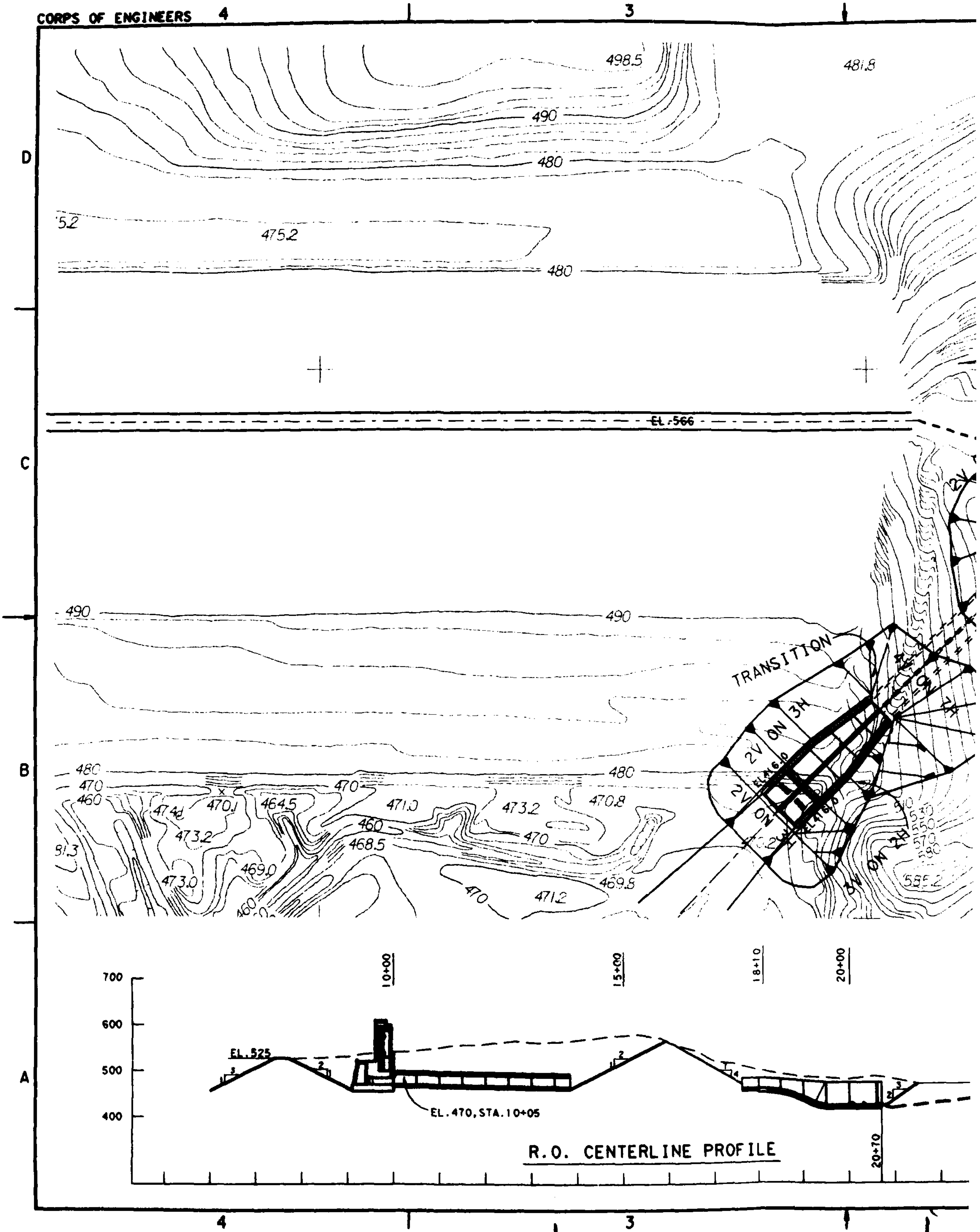
ONE-LINE DIAGRAM

SUBMITTED BY:
NEAL R. HANSON, P.E.
CHIEF, DESIGN BRANCH

DATE APPROVED 30 Sept. 1987

SPEC. NO. DACW09-__ B-__
DISTRICT FILE NO. HPP-P-10

SHEET 10


CORPS OF ENGINEERS
4
3
D
C
B
A
498.5
481.8
490
480
475.2
480
EL. 566
490
490
TRANSITION
2V ON 3H
2V ON
EL. 416.0
2V ON 2H
480
470
460
480
474.d
470.1
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470
471.0
473.2
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473.0
469.8
470
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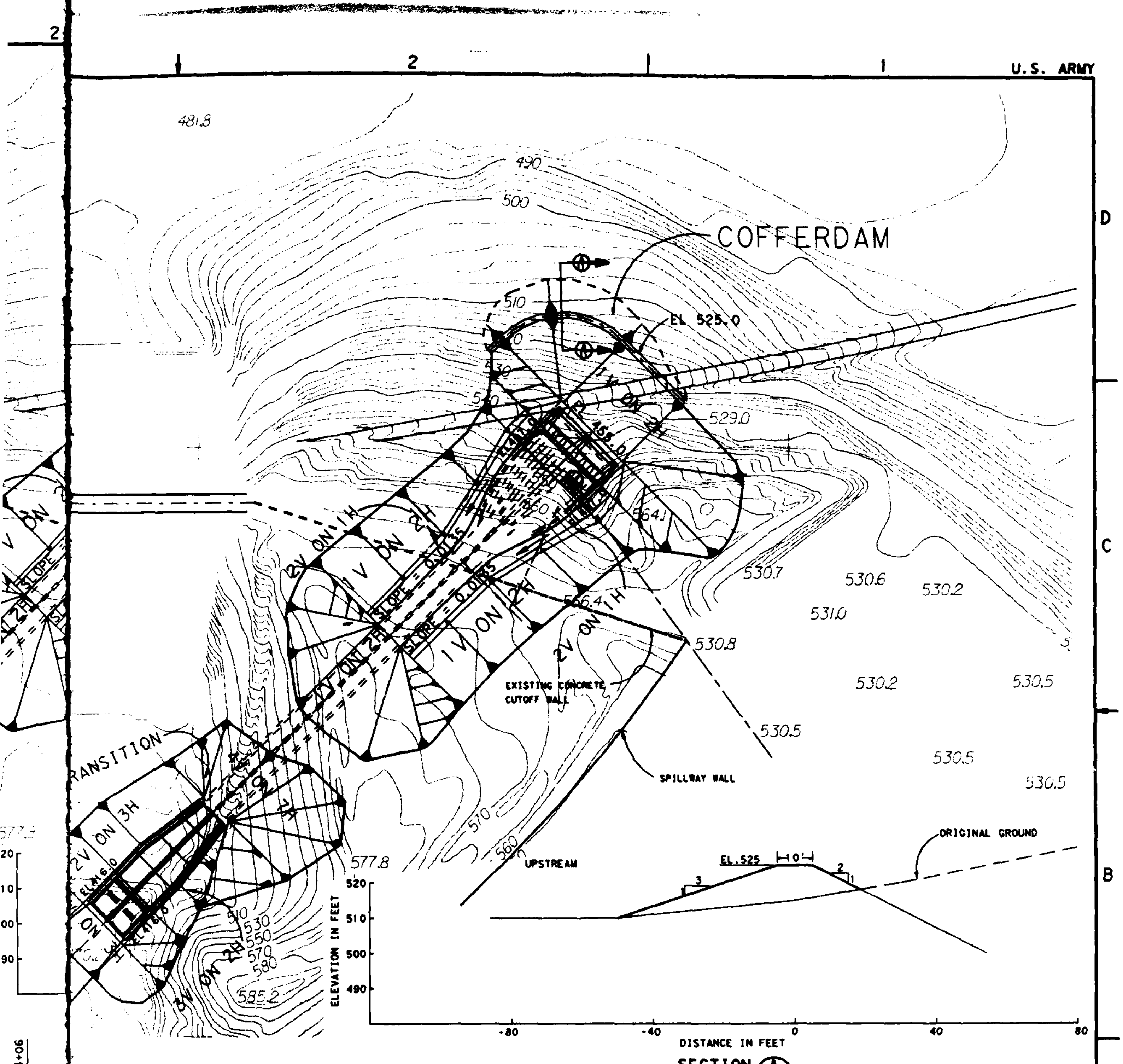
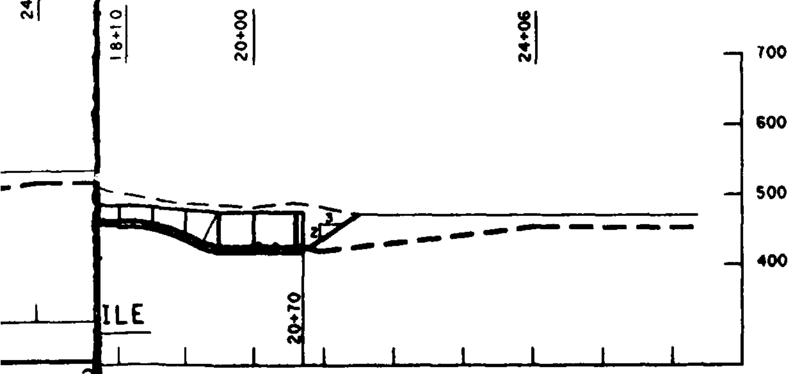
585.2
700
600
500
400
10+00
15+00
18+10
20+00
EL. 525
EL. 470, STA. 10+05
20+70
R.O. CENTERLINE PROFILE



SECTION A



REVISIONS

SYMBOL	DESCRIPTION	DATE	APPROVAL

U.S. ARMY ENGINEER DISTRICT
PORTLAND
CORPS OF ENGINEERS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: KKY
DRAWN BY: P.LU
CHECKED BY:

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
PLAN & PROFILE
STAGE I CONSTRUCTION

SUBMITTED BY:
DATE APPROVED:
STEVEN L. STOCKTON, P.E. 1987 SEPT. 30
CHIEF, GEOTECHNICAL BRANCH

SPEC. NO. DACW09-___ B-___
DISTRICT FILE NO. NPP-P-11

SHEET
11

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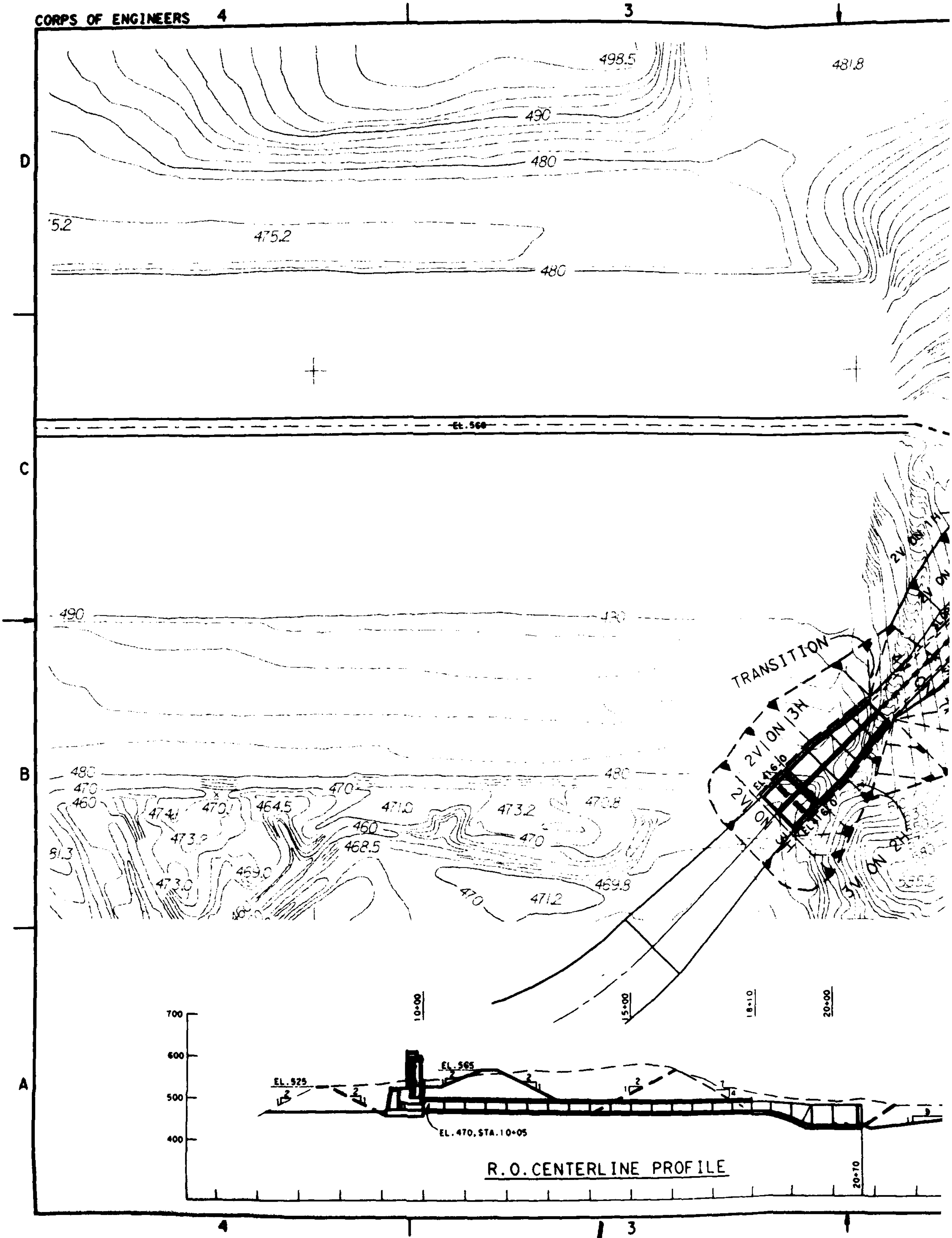
CORPS OF ENGINEERS
4
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498.5
481.8
490
480
5.2
475.2
480
EL. 560
490
490
TRANSITION
2V ON 1H
2V ON 3H
2V ON
EL. 416.0
3V ON 2H
480
470
460
474.1
470.1
464.5
470
471.0
473.2
470.8
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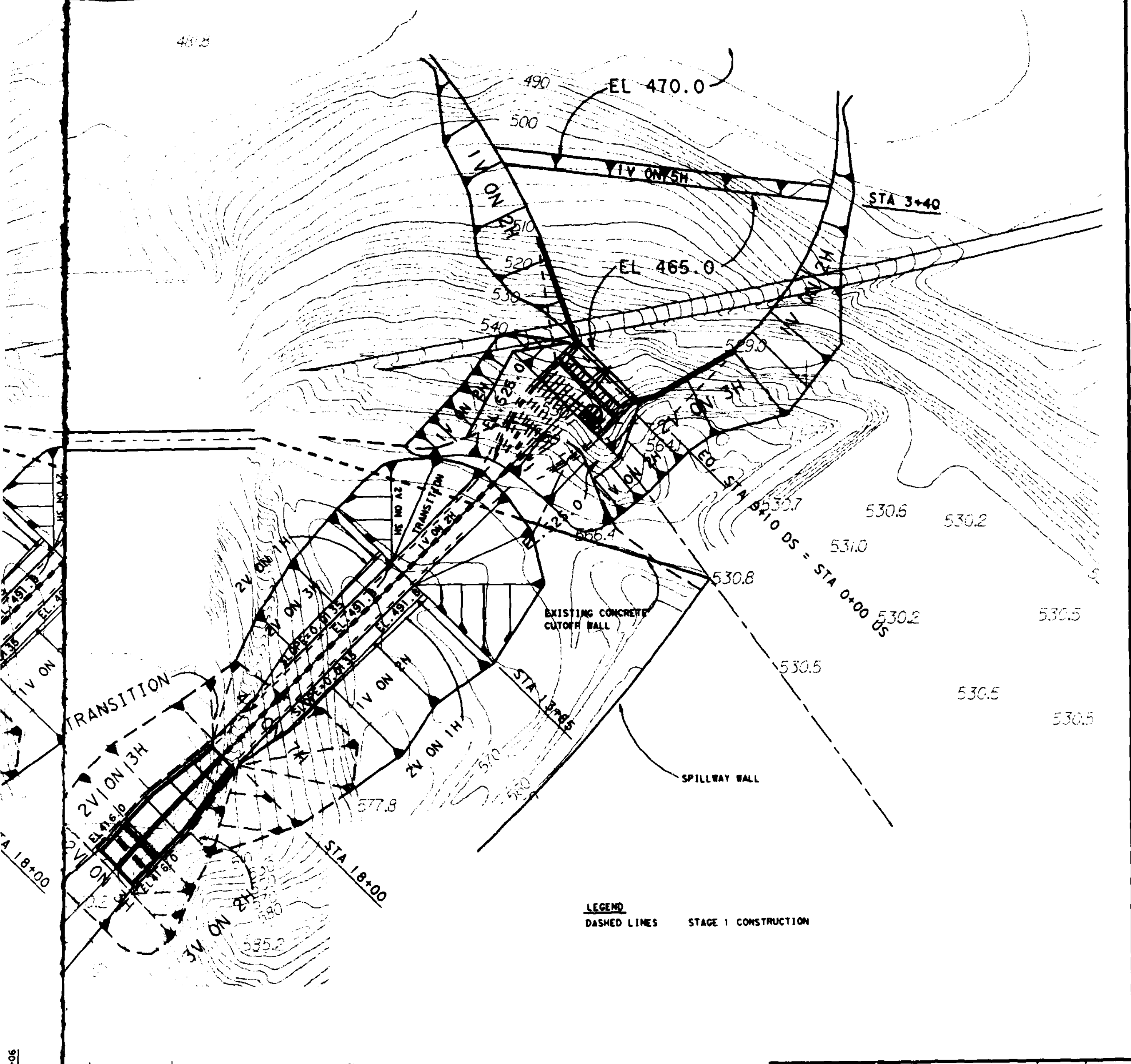
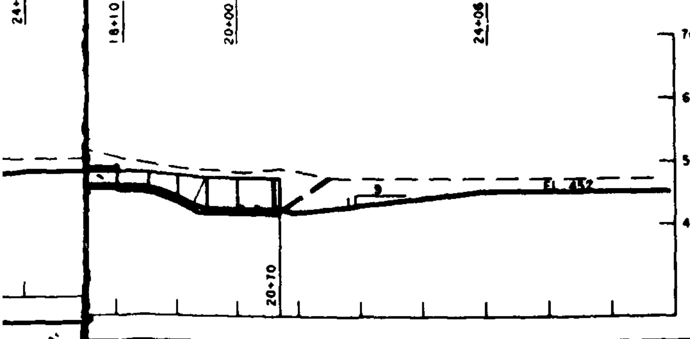
473.2
460
468.5
470
81.3
473.0
469.0
470
471.2
469.8
10+00
15+00
18+10
20+00
700
600
500
400
EL. 525
EL. 565
EL. 470, STA. 10+05
20+10
R.O. CENTERLINE PROFILE

U.S. ARMY





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MARK	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT
PORTLAND
CORPS OF ENGINEERS

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: KKY

DRAWN BY: P.LU

CHECKED BY:

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
PLAN & PROFILE
STAGE II CONSTRUCTION

SUBMITTED BY:
STEVEN L. STOCKTON, P.E.
CHIEF, GEOTECHNICAL BRANCH

DATE APPROVED: 1987 SEPT. 30

SPEC. NO. DACW09- ___ B- ___

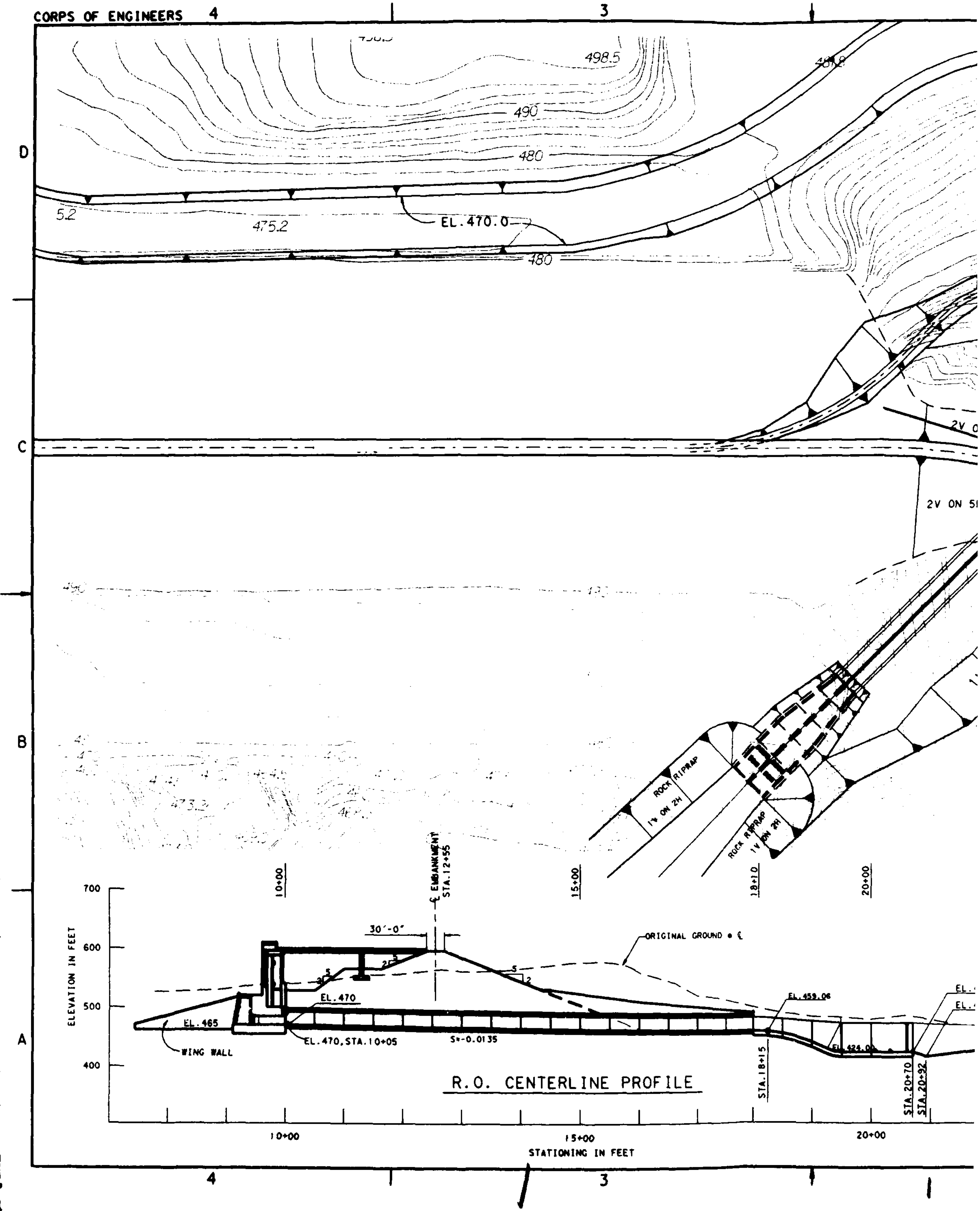
DISTRICT FILE NO. MPP-P-12

SHEET 12

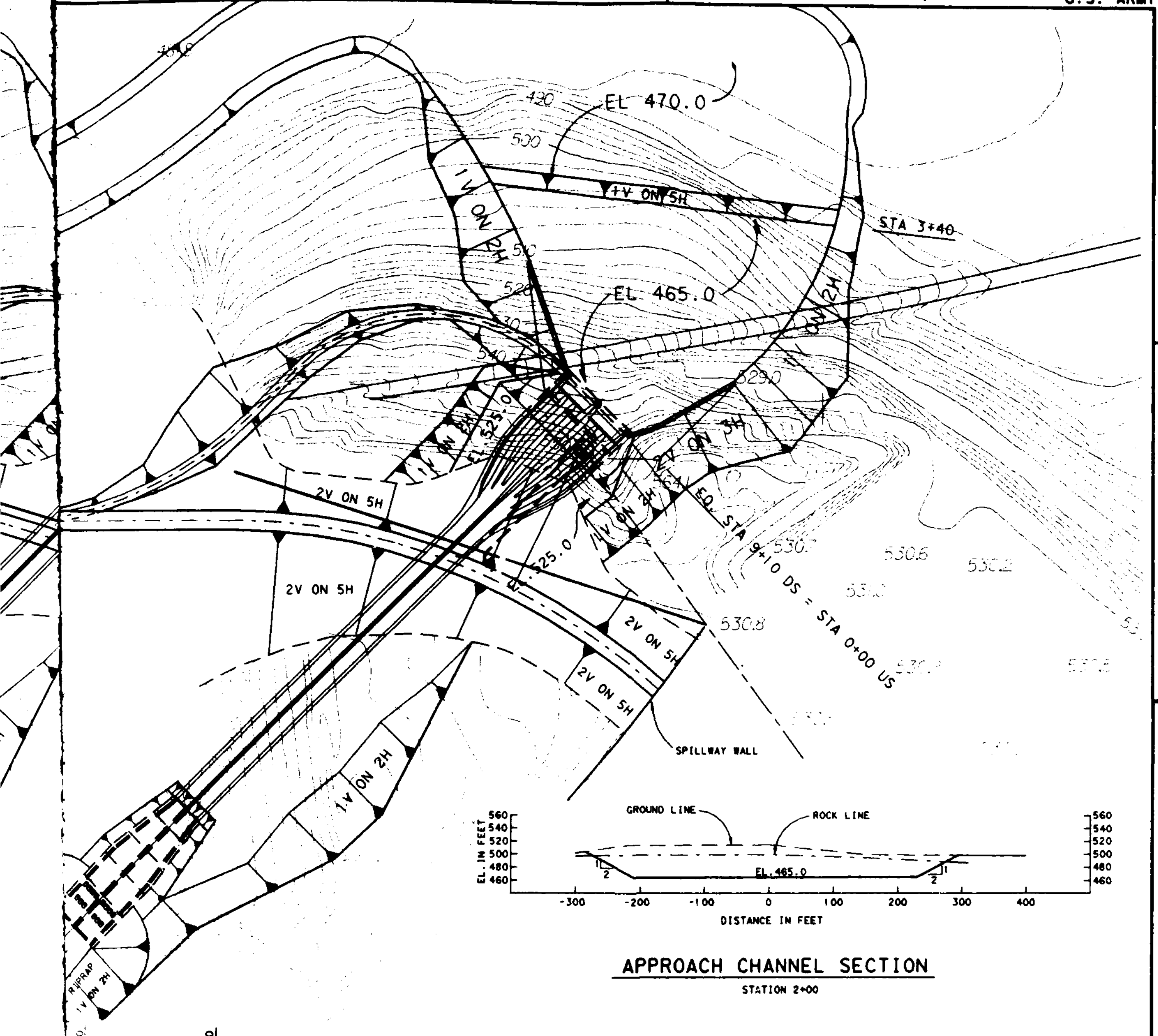
PLATE C-12

2

CORPS OF ENGINEERS

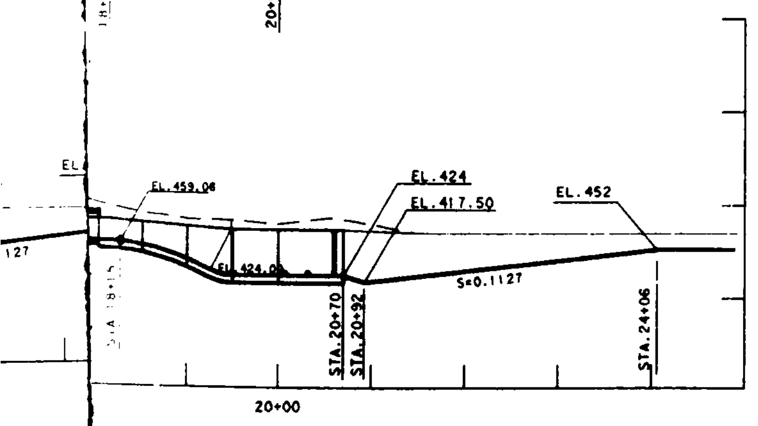


U.S. ARMY



APPROACH CHANNEL SECTION

STATION 2+00



SYMBOL	DESCRIPTION	DATE	APPROVAL

REVISIONS

U.S. ARMY ENGINEER DISTRICT PORTLAND CORPS OF ENGINEERS	U.S. ARMY ENGINEER DISTRICT LOS ANGELES CORPS OF ENGINEERS

DESIGNED BY: KKY

DRAWN BY: P.LU

CHECKED BY:

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

PRADO DAM
OUTLET WORKS
PLAN & PROFILE
STAGE III CONSTRUCTION

SUBMITTED BY: STEVEN L. STOCKTON, P.E.
CHIEF, GEOTECHNICAL BRANCH

DATE APPROVED: 1987 SEPT. 30

SPEC. NO. DACW09-___ B-___

DISTRICT FILE NO. NPP-P-13

SHEET 13

CADD DESIGN FILE:
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PLATE C-13

2

AD-A204 542   SANTA ANA RIVER DESIGN MEMORANDUM NUMBER 1 PHASE 2 GDM   8/10
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ANGELES CA   AUG 88

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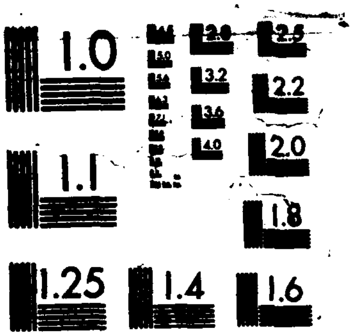


MICROC

RESOURCE USE PLAN

PREFACE

P-01 The purpose of this Resource Use Plan is to provide guidance for the orderly development and coordinated management of lands at Prado Basin. The Plan has been developed based on an assessment of all resources in the basin and recommends potential compatible uses.

P-02 Chapters 1 and 2 provide background information on the basin and the scope of this study. Chapter 3 provides an overview of how the Plan was prepared. Chapter 4 describes the Plan in detail. Chapter 5 outlines how to implement the Plan in terms of future development and management of the basin. Chapters 6, 7, 8 and 9 provide the guidelines and background information necessary to implement the Plan. Chapter 10 describes management and cost sharing. Chapter 11 lists the conclusions and recommendations of this study.

P-03 In summary, this study provides a Resource Use Plan and provides guidelines to implement it.

CONTENTS

CONTENTS (Continued)

Tables

CONTENTS (Continued)

Tables (Continued)

Figures

Plates

I. INTRODUCTION

1-01 The Prado Dam Flood Control Basin presently serves as the major flood control facility along the Santa Ana River corridor. Since the completion of Prado Reservoir in 1941, urbanization and related development pressures have increased adjacent to and below the basin. A flood hazard exists within the rapidly developing urban areas of Orange, Riverside, and San Bernardino Counties. As urbanization of the area increases, this hazard grows. Without further flood control improvements along the Santa Ana River, future floods could cause significant damages and would jeopardize the lives of the people who live or work in the floodplain.

1-02 Expansion of Prado Basin has been proposed to alleviate this potential threat. In conjunction with the proposed expansion of Prado Reservoir, the United States Army Corps of Engineers (COE) prepared this report to serve as a comprehensive guide for land use planning within the Prado Basin. The Resource Use Plan is not site specific. Rather it recommends potential compatible uses with the resources of Prado Basin, characterizes the basin's present land use, and provides restraints on development due to flooding.

Project Authorization

1-03 Construction of Prado Dam was authorized by the Flood Control Act of 1936 (Public Law 74-738) as amended, as part of a general plan for the construction of flood control facilities in the Santa Ana River Basin, California. Construction of the dam was completed in May 1941. The Flood Control Act of 1944 (Public Law 78-534), as amended, authorized the COE to construct, maintain, and operate public park and recreational facilities at water resource development projects. The law also permitted the COE to authorize local interests to construct, maintain and operate recreational features.

1-04 The study of the recreation potential of the Prado Basin was authorized under the Federal Water Project Recreation Act of 1965, Public Law 89-72, whereby full consideration must be given to the opportunities for outdoor recreation and for fish and wildlife enhancement that is afforded by water resources development projects; and the Water Resources Development Act of 1976, section 109, including recreation as a stated project purpose. The Phase I General Design Memorandum, including recreation as a project purpose, was submitted in September 1980.

Purpose of the Resource Use Plan

1-05 The purpose of the Resource Use Plan is to provide guidelines for the orderly and coordinated management and development of all land and water resources within the Prado Basin. It is not intended as an absolute or definitive plan detailing all specific development features that may be considered in the future. Instead, the plan provided guidance for evaluating specific proposals for future development.

1-06 The Resource Use Plan serves as a guide for determining land use planning issues within the Prado Basin. As a result of the present economic situation new recreation facilities developed for public use must generally be self supporting and economically viable, and capable of paying for their own operation and maintenance. In view of this consideration local agencies must frequently rely on concessionaire development of facilities to meet public recreation needs. It is extremely difficult to predict what specific proposals will constitute an economically viable enterprise in the future, because of shifting trends in recreation needs by the public. The Resource Use Plan is intended as a general guide to assist in determining the capability of the Prado Basin to accommodate specific development proposals.

Scope

1-07 The Resource Use Plan will function as a guide not only for the COE, but also for county and city planning officials and private developers. The Plan has been developed based on an assessment of all resources in the Basin and recommends potential compatible uses which reflect opportunities and constraints on management and development due to flooding which are in accord with COE regulations and polices.

1-08 The general intent of the Resource Use Plan is to identify potential conflicting land uses, not to attempt to resolve those specific conflicts. The flood control project proposed for the Prado Basin is unique in that it is essentially a project that supercedes a previous COE project, and as such, must recognize existing land area and developments that, in some cases, are in direct conflict with the Resource Use Plan. It is anticipated that future efforts will either mitigate or resolve the conflicts.

1-09 The study provides the process necessary to evaluate specific development or management activities. Detailed guidelines and background information is provided to facilitate site specific decisions.

1-10 The following chapters will be useful to anyone implementing the Plan: Chapter 3, which explains how the Plan was developed; Chapter 4, which describes the Plan; Chapter 5, which outlines the implementation process; and Chapters 6 though 9 which provide detailed guidelines and background information necessary to implement the Plan during specific site studies.

Application of Public Laws

1-11 The following laws provide for the development and management of Federal projects for various purposes according to the intent of Congress:

a. Public Law 78-534 (The Flood Control Act of 1944), as amended by the Flood Control Acts of 1946, 1954, 1960, 1962, and 1965, authorizes the COE to construct, maintain, and operate public park and recreational facilities at water resources development projects, and to permit local interests to construct, maintain and operate such facilities.

b. Public Law 85-624 (The Fish and Wildlife Coordination Act of 1958) requires that the COE and any agency impounding, diverting, or controlling water consult with the United States Department of the Interior, Fish and Wildlife Service. The Department of the Interior would determine the possible damage resulting to wildlife resources and the measures needed to prevent such damage, and would provide for the development and improvement of such resources.

c. Public Law 89-72 (The Federal Water Project Recreation Act of 1965), accompanied by House Committee Report No. 254, requires that the COE and other Federal agencies give full consideration to fish and wildlife enhancement. It also provides for non-Federal participation in land acquisition and in the development and management of recreational facilities and fish and wildlife resources.

d. Public Law 89-665 (The National Historic Preservation Act of 1966), as amended in 1980, directs the COE and other Federal agencies to provide leadership in preserving, restoring and maintaining the historic and cultural environment of the Nation.

e. Public Law 90-542 (Wild and Scenic Rivers Act, as amended through Public Law 96-580, December 23, 1986), institutes a national wild and scenic rivers system, by designating the initial components of that system, and prescribes the methods by which additional components may be added to the system.

f. Public Law 91-190 (The National Environmental Policy Act of 1969), requires that an environmental impact statement be filed by the COE and other agencies describing the environmental effects of each project having a significant impact on the environment, and the means and measures necessary to minimize any adverse effect. An environmental assessment has been prepared regarding this Plan. This assessment was prepared to supplement the Plan.

g. Public Law 91-604 (The Clean Air Act, as amended in 1970, 1977), specifies that any Federal activity which may result in discharge of air pollutants must comply with Federal, state, interstate, and local requirements respecting control and abatement of air pollution.

h. Public Law 91-611 (River and Harbor and Flood Control Act of 1970), directs the Secretary of the Army, acting through the Chief of Engineers, to promulgate guidelines for consideration of significant economic, social, and environmental effects of proposed water resources developments, so that final project decisions are made in the best overall public interest.

i. Public Law 93-205 (The Endangered Species Act of 1973), requires Federal agencies to utilize their authorities to carry out programs for conservation of endangered and threatened species protected by the Act.

j. Public Law 95-217 (Clean Water Act of 1977, as amended), established a National goal of eliminating all pollutant discharges into United States waters during the 1980's and an interim goal of making the waters safe for fish, shellfish, wildlife and people (Section 101).

k. Public Law 97-98 (Farmland Protection Policy Act, 22 December 1981), requires Federal agencies to identify and take into account the adverse effects of Federal programs on the preservation of farmland; consider alternative actions, as appropriate, that could lessen such adverse effects; and assure that such Federal programs, to the extent practicable, are compatible with State, unit of local government, and private programs and policies to protect farmland.

l. Executive Order 11990 (Protection of Wetlands, 24 May 1977), recognizes the significant values provided by wetlands warranting specific measures for their preservation.

m. Executive Order 11988 (Floodplain Management, 24 May 1977), requires that the COE and other Federal agencies prevent avoidable adverse or incompatible developments in floodplains by assessing a proposed course of action, considering alternative approaches when adverse effects would result, and formulating designs and project modifications in order to minimize the potential harm.

n. Executive Order 11593 directs Federal agencies to locate, evaluate, and manage all cultural resources on lands owned or controlled by the agency.

Applicable Regulations

1-12 The following regulations provide policy and guidance during the preparation of the plan:

a. ER 1120-2-400 (Recreation Resources Planning, November 1971) prescribes policies, guideline procedures and definitions for insuring that protection and enhancement of recreation resources are given equal treatment with other objectives in the planning and development of water resource projects under the jurisdiction of the COE. A key feature of this regulation is the definitions provided for land use allocation categories applicable to Corps projects.

b. ER 1130-2-400 (Project Operation--Management of Natural Resources and Outdoor Recreation at Civil Works Water Resource Projects, June 1986) provides policy and procedural guidance for the administration and management of civil works water resource project only. General policies regarding planning, authorization, development and construction of civil works projects are contained in references and in other regulation and policy statements.

c. ER 1165-2-400 (Recreation Planning, Development and Management Policies, August 1985) defines the objectives, philosophies and basic policies for the planning, development and management of outdoor recreation and enhancement of fish and wildlife resources at COE water resource development projects.

d. ER 1105-2-50 (Environmental Resource Planning, August 1984) provides requirements for addressing environmentally sensitive planning techniques consistent with the National Environmental Policy Act of 1969 and project lands.

e. ER 1105-2-167 (Establishment of Resource Use Objectives, April 1978) provides policy and guidance for establishing resource use objectives for all civil works water resource projects.

f. ER 200-2-2 (Environmental Quality: Policy and Procedures of Implementing NEPA, August 1980) provides policy and procedural guidance to supplement the Council on Environmental Quality final regulations implementing the procedural provisions of NEPA.

1-13 The above mentioned laws and regulations do not preclude a consideration of proposed development within the basin.

II. PROJECT BACKGROUND

2-01 The Santa Ana River Phase I General Design Memorandum presented a recreation plan that was based on the recreation plan previously presented in the 1980 Survey Report. Both plans were based on the development of water-oriented recreation facilities surrounding multipurpose lakes to be developed within the Prado Basin. During the review process of the Santa Ana River Phase I GDM for the "All River Plan" at the Board of Engineers for Rivers and Harbors (BERH), the question of development of multipurpose lakes within dry land reservoirs was referred to the Office of Policy for review and comment. The determination of the Office of Policy was that there is no authority available to the Corps under the Santa Ana River Project for the construction of such lakes, even though similar lakes within the Prado Basin had been previously developed with 50/50 cost sharing under the COE Code 710 Program (recreation development at completed COE projects). In view of this policy determination, the direction provided was that the recreation plan for the Prado Basin should be reformulated during the preparation of the Phase II General Design Memorandum. A further restriction placed upon the formulation of recreation plans within the Prado Basin concerned the trail system that had previously been proposed in the Survey Report. The Survey Report had proposed a trail system to connect the Prado Basin with the upstream storage site, Mentone Dam. Subsequent to review of the report by BERH, however, it was determined that there was no Federal interest in the trail system, since no lands were proposed for Federal acquisition and would be subject only to flood plain management.

2-02 During the initial reformulated recreation studies for the Prado Basin there was no direct interest or ability on the part of any of the potential local sponsors to participate in site-specific cost shared recreation facilities. As a result of this lack of interest on the part of the potential local sponsors, the COE decided to proceed independently and prepare a Resource Use Plan based on land use analysis, and environmental sensitivity and suitability, which would provide a guide for all future development within the Prado Basin. The

Resource Use Plan, presented as an integral part of this Phase II General Design Memorandum, establishes four different intensity levels and provides guidelines to assist in the determination of appropriate land uses within each intensity level.

2-03 Within the past year, all concerned potential local sponsors have experienced a rather dramatic administrative turnover, and their viewpoints concerning recreation philosophy and public needs is markedly different than their predecessors. These agencies are presently developing more detailed site-specific recreation development proposals for their areas of interest within the Prado Basin. Subsequent Feature Design Memorandums will be prepared to outline proposed development that is eligible for 50/50 cost sharing under current COE policy and guidelines.

III. PLAN FORMULATION

3-01 This chapter describes the process of developing the Resource Use Plan. Each step of the process is described in sections below, including formulation of study goals, collection and analysis of Plan guidance variables, formulation of resource use objectives and preparation of the Resource Use Plan.

Definition of Study Goals

3-02 The basic goal of this study is to provide a guide for land use planning and development within Prado Dam Basin. To this end, four objectives are defined:

a. Utilize the report to serve as a guide for land use planning useful to both COE staff, county and local officials, as well as private developers.

b. Provide a Resource Use Plan which reflects Federal regulations and policy which minimizes flood damage to property and protects and enhances specific environmental resources.

c. Provide guidelines for evaluating proposed uses and developments, including resource use objectives, resource element data, flood inundation level constraints and existing land use and site feature data.

d. The preservation of the flood control integrity of the Prado Basin, and the appropriate consideration of proposed development.

Identification of Resource Use Plan Guidance Variables

3-03 The Resource Use Plan will function as a guide not only for the COE, but also for county and city planning officials and private developers. Two main guidance variables have been identified upon which

the Plan is structured. They include resource elements, including existing land uses, and flood inundation levels. In addition, existing site features is an additional variable that should be consulted in the overall analysis. Each variable is outlined below as to its specific function and how it relates to the other variables in providing land use planning guidance.

RESOURCE ELEMENTS

3-04 A resource element is a resource identified in the basin as providing vital land use planning guidance. Six resources within the basin have been identified as resource elements. They include biological, cultural, topographic slope, soil erosion potential, visual quality resources, and existing land uses. Three of the resource elements, biological and cultural resources, and existing land uses, have been identified as key elements in the Plan; however, all six resources are to be used in the review of proposed land uses for the basin. Resource element information was analyzed in detail (see Chapter 7) and, in conjunction with flood inundation levels data comprises the Resource Use Plan plate (Plate 1). Review of proposed uses should first consider the Resource Use Plan in the review process. This will aid in preliminary determination of whether significant resources will likely be affected by proposed uses.

3-05 Existing land uses have been identified in the basin. Existing uses were incorporated into the Plan plate. Existing land uses are not preempted by the Plan. In some instances current land uses may be in conflict with the Plan and accompanying land use guidelines. Potential expansion proposals of existing uses as well as similar use proposals elsewhere in the basin will be analyzed on a site specific case by case basis with the Plan and associated land use guidelines. Conflicting land uses, whether currently proposed or to be proposed in the future, will not necessarily be precluded from development, as case by case mitigation measures are developed, approved and implemented to offset any impacts to significant resources.

FLOOD INUNDATION LEVELS

3-06 Flood inundation level data was incorporated in the analysis to provide for the development of guidelines as to the placement and type of structures in order to realize minimization of damage caused by flooding. Flood inundation levels reflect the debris pool, the 10, 50, and 100 year flood elevations, as well as the reservoir design flood elevation. Additionally, the flood boundaries and flood fringes are included for the Santa Ana River and Temescal Wash above the 100-year flood elevation. This information is not necessary for Chino and Cucamonga Creeks, since they are channelized. The 100-year floodplains for the Santa Ana River, Temescal Wash, and Chino and Cucamonga Creeks are delineated below the 100-year flood inundation level extending to the debris pool. Review of proposed uses should first consider the Plan with incorporation of flood inundation level information in the review process. This will aid in preliminary determination of whether proposed uses will likely be affected by flood conditions and to what degree.

EXISTING SITE FEATURES

3-07 Several features have been identified in the basin as providing site specific guidance for determining potential opportunities or conflicts with basin resources. This data is presented for reference in investigating site specific land use proposals that first have been reviewed with the Plan and associated flood inundation level information and existing land uses. Such features include location of oil and gas wells, geology (i.e., location of faults and potential borrow areas), prime and unique farmland, miscellaneous utilities (i.e., major sewer lines) and master recreation outgrant boundaries.

Identification of Resource Use Objectives

3-08 Resource use objectives are intended to guide the design, appropriate use, development and management of the natural and other resources of the project to maximize benefits by meeting public needs and protecting and enhancing environmental quality. Planning for the basin's resources consistent with established resource use objectives will help insure the preservation, conservation, and enhancement, and thus the future availability, of basin resources in balance with achieving the best and highest use of the basin.

3-09 The objectives below translate the issues, opportunities and constraints derived from all Resource Use Plan guidance variables (Chapters 3, 7, 8 and 9) into direction for the Plan.

3-10 A series of items have been identified as the essential general resources of the basin:

- Environmental Quality and Character
- Recreation
- Education and Interpretation
- Open Space
- Commercial and Industrial Operations
- Energy Resources
- Water
- Soil Resources
- Air Quality
- Esthetics
- Cultural Resources
- Wildlife
- Vegetation

3-11 For each item, an objective has been developed. The objectives presented below are broad statements for the purpose of planning the resource use of Prado Basin. More specific objectives have been developed for the purpose of development and management of Prado Basin (Chapter 6). The objectives are as follows:

a. Environmental Quality and Character - Protect and conserve the overall environmental quality and character of the basin, as well as the quality and character of the unique and important natural and cultural resources which comprise the basin.

b. Recreation - Develop a variety of recreation opportunities of a regional nature which will serve a broad cross section of socioeconomic needs.

c. Education and Interpretation - Increase awareness and understanding of the basin's significant resources through educative and interpretive measures.

d. Open Space - Preserve open space to support and protect wildlife habitat, cultural resources, interim agricultural land uses, recreational land uses, and the environmental and visual character of the basin.

e. Commercial and Industrial Operations - Provide opportunities for commercial, and industrial operations in the basin.

f. Energy Resources - Increase regional energy self-sufficiency and the efficiency with which energy is used in the basin.

g. Water - Prevent further degradation of and if possible improve water quality within the basin and investigate the basin's potential role for increasing the efficiency of regional water use.

h. Soil Resources - Conserve soil resources within the basin.

i. Air Quality - Manage the resources, activities, and land uses within the basin in a manner that will not further degrade the air quality both within the basin and in the surrounding region.

j. Esthetics - Preserve and protect the rural, pastoral, open space, and natural esthetic quality and character of the basin.

k. Cultural Resources - Conserve cultural resources within the basin through preserving appropriate sites, providing interpretative opportunities, and by improving knowledge of these resources.

l. Wildlife - Protect and maintain wildlife resources.

m. Vegetation - Preserve and, where possible enhance vegetation in the Prado Basin.

Resource Use Plan Study Methodology

3-12 The following discussion focuses on the methodology employed in the preparation of the Resource Use Plan and supporting documentation.

3-13 Subsequent to an identification of study goals, as identified in previous discussion, it was determined that a map overlay analysis would be the most appropriate for this study. This analysis method requires the following steps be taken: identify basin resources for analysis inclusion; distinguish between important (resource elements) and secondary resources (site features) and identify each resource's analysis function; develop resource use objectives; define for important resources (resource elements) appropriate interpretations for detailed analysis and conduct data collection and mapping at a common scale; for secondary resources (site features), collect and map data at a common scale; develop land use guidelines for use with the Plan plate; and conduct overlay analysis of important resources (resource elements) to produce the Resource Use Plan plate.

3-14 Numerous basin resources were identified for the study and a distinction made between important and secondary resources as well as an identification of each resource's analysis function. Table D-1 displays the resources appropriately defined.

3-15 During the course of the study, six resource elements were identified as important to guiding land use in the basin: biological resources, cultural resources, soil erosion potential, topographic slope, visual quality and existing land uses. The first intention was to utilize all six elements in determining the Resource Use Plan plate. However, based on existing Federal regulations and COE policy, it was determined that the biological, cultural and existing land uses resource elements would be the most useful and supportive land use determinants. The remaining three resource elements will be used in the course of the review process, providing further refinement to preliminary conclusions provided by the Resource Use Plan plate.

3-16 Appropriate interpretations for important resources are outlined in Chapter 6. Collected data was then mapped in accordance with interpretations at a common scale.

3-17 The Resource Use Plan reflects land use restrictions based on two major determinants: resource sensitivities, including existing land uses, and flood inundation levels.

3-18 Resource sensitivities reflect the sensitivities of the biological and cultural resources within the basin. Both resources, as stated previously are protected by Federal regulations and COE policy. Flood inundation levels reflect restrictions on land use specifically to minimize loss of property and to minimize potential danger to the safe and efficient operation of the flood control facility. The latter bears a direct relationship to the location and type of structures allowed within the basin. Existing land uses were directly incorporated into the analysis as part of the Plan.

3-19 The map overlay analysis was then conducted in accordance with land use guidelines established during the resource identification and interpretation stages. The land use guidelines follow the format as shown in table D-2.

3-20 As indicated in table D-2, the land use categories '1" through "4C" reflect low to more intense uses. The compatible uses indicated reflect both the sensitivities of the selected resources and COE knowledge of uses compatible to a specific frequency of flooding.

Table D-1. Basin Resources Incorporated in Resource Use Plan - Defined by Analysis Function.

Resource Elements	
Biological Resources	Data coded per sensitivity to potential intensities of use. Biological and cultural resource sensitivities serve as key determinants in the proposed land use suitability map.
Cultural Resources	
Soil Erosion Potential	
Topographic Slope	
Visual Quality	
Flood Inundation Levels	
Flood Inundation Levels	Flood control levels used to determine potential restrictions to uses.
Existing	
Climate	"Raw" data not qualified. Used as reference and as means to determine potential opportunities or conflicts with current and future land use planning efforts.
Circulation	
County and Local Zoning	
Surface Water Quality	
Prime and Unique Farmland	
Geology	
Oil and Gas Leases	
Oil and Gas Wells	
Master Recreation Outgrant Boundaries	
Recreation Outgrants/Ownership	
Agriculture Outgrants	
Major Flowage Easements	
Miscellaneous Utilities	

3-21 To develop the Resource Use Plan plate, the selected resources and the flood inundation levels were overlayed, identifying first those areas with the greatest restriction to land use improvements. Thus, land use category "1" contains the extreme sensitivity values of the biological and cultural resources as well as the debris pool and areas of flood boundaries above the 550' elevation. If any one data element value overlayed a less restrictive data element value, the more restrictive value was always applied.

3-22 While the majority of the land use categories ("1", "2", "4B", "4C") have distinct restraints imposed by flood inundation levels, land use categories "3" and "4A" share the restraints imposed by the flood inundation level 514-534. This is due to the fact that while land use

categories "3" and "4A" are distinguished environmentally, both can accept the described structure type imposed by the flood inundation level since the structure's implied intensity of use does not conflict with the environmental restraints of the resources.

3-23 Users of the Resource Use Plan plate must understand that the plate reflects typical uses. This allows COE staff to consider a variety of uses, utilizing the Plan plate as a guide in the review process. If apparent conflicts in the interpretation of policy arise in the review process, the COE will apply the most restrictive interpretation. Additionally, the COE considers existing uses as "grandfathered" into the Plan. However, any proposed alteration, revision, or expansion of such uses will be subject to COE review of the compatibility of the proposed change with the Plan.

Table D-2. Example of Land Use Guidelines - Land Use Categories and Potential Uses.

Land Use Category	Potential Compatible Uses	Potential Structures	Flood Inundation Levels
1	Fish & wildlife management	No Structures	Debris Pool and Flood Boundary above 550' elevation
2	Open space low intensity uses that maintain resource values	No Structures	500-514
3	Bicycle Trails	Open type or floodable structures with portable contents	514-534 and River Floodplains below 550' elevation
4A	Sports Fields	Open type or floodable structures with portable contents	514-534 and River Floodplains below 550' elevation
4B	Paved Areas	Open type or floodable structures	534-550
4C	Equestrian Centers	Closed flood proofed structures	550-566 and Flood Fringe above 550' elevation

IV. RESOURCE USE PLAN

4-01 As stated in Chapter 3, the Resource Use Plan plate for Prado Basin reflects land use restrictions based on two major determinants: resource sensitivities, including existing land uses, and flood inundation levels.

4-02 COE staff will evaluate the suitability of proposed land uses and projects on Federal land within the standard project flood zone of Prado Basin.

4-03 County and city planning officials, in coordination with private developers when applicable, can utilize this Plan when making recommendations on proposed development on non-Federal land within the standard project flood zone of the basin, taking into consideration COE flowage easement restrictions.

4-04 Resource sensitivities reflect the sensitivities of the biological and cultural resources within the basin. Both resources, as stated previously are protected by Federal regulations and COE policy. Another resource element, existing land uses, is directly incorporated into the analysis as part of the Plan. Existing land uses are not preempted by the Plan. Flood inundation levels reflect restrictions on land use specifically to minimize loss of property and to minimize potential danger to the safe and efficient operation of the flood control facility. The latter bears a direct relationship to the location and type of structures allowed within the basin.

4-05 Refer to table D-3 for the land use guidelines that accompany plate 1.

4-06 Users of the Resource Use Plan plate must understand that the plate reflects potential compatible uses. This allows for a consideration of a variety of uses, utilizing the Plan plate as a guide in the review process. If apparent conflicts in the interpretation of policy arise in the review process, the COE will apply the most restrictive

interpretation. Additionally, the COE considers existing uses as "grandfathered" into the Plan. However, any proposed alteration, revision, or expansion of such uses will be subject to review of the compatibility of the proposed change with the Resource Use Plan.

4-07 Chapter 5 explains the review process used for all proposed uses and development.

Table D-3. Resource Use Plan Land Use Guidelines.

Land Use Category	Potential Compatible Uses	Potential Structures	Flood Inundation Levels
1	Fish and wildlife management Interpretation/education Hiking (limited*) Equestrian trails (limited*)	No Structures	Debris Pool and Flood Boundary above 550' elevation
2	Open space low intensity uses that maintain resource values	No Structures	500-514
3	Agriculture Bicycle Trails Equestrian Trails Hiking Trails Casual/Informal Play Areas Camping Picnic Areas Golf Courses Concession stands with portable contents	Open type or floodable structures with portable contents	514-534 and River Floodplains below 550' elevation
4A	Sports Fields *Swimming* Beaches Interpretive Structures	Open type or floodable structures with portable contents	514-534 and River Floodplains below 550' elevation
4B	Paved Areas Parking Boat Launches Restrooms	Open type or floodable structures	534-550
4C	Equestrian Centers Visitor Centers	Closed flood proofed structures	550-566 and Flood Fringe above 550' elevation

*Note: Limitations on hiking and equestrian trails will be determined on a case by case basis.

Table D-3. (Continued)

Land Use Category	Existing Land Uses
Existing Land Uses Locations by Land Use Categories	
1	El Prado Golf Course Prado Recreation Inc. agricultural leases Splatter S. Duck Club Raahague Duck Hunting Clubs gas and oil wells Corona Municipal Airport percolation ponds Prado Basin Park Prado Basin Park (undeveloped)
2	Chino Basin Sewage Treatment Plant #2 El Prado Golf Course Tiro Shooting Range Prado Regional Park Prado Recreation Inc. Raahague Duck Hunting Club gas and oil wells Butterfield Park Corona Municipal Airport percolation ponds rifle and pistol range Prado Basin Park Prado Basin Park (undeveloped) agricultural leases
3	Chino Basin Sewage Treatment Plant #2 El Prado Golf Course Tiro Shooting Range archery range Prado Regional Park Prado Recreation Inc. percolation ponds rifle and pistol range Prado Basin Park (undeveloped) Raahague Duck Hunting Club agricultural leases
4A 4B 4C	Chino Basin Sewage Treatment Plant #2 El Prado Golf Course Tiro Shooting Range archery range Raahague Duck Hunting Club agricultural leases gas and oil wells

Table D-3. (Continued)

Land Use Category	Existing Land Uses
Existing Land Uses Locations by Land Use Categories (continued)	
	Prado Regional Park
	Prado Recreation Inc.
	Corona Wastewater Treatment Plant
	Butterfield Park
	Corona Municipal Airport
	percolation ponds
	rifle and pistol range

Explanatory Notation to be Used With the Resource Use Plan Land Use Categories

* Land use categories reflect the most restrictive uses determined by the resource element and/or the flood inundation levels. When apparent conflicts exist, the most restrictive policy will apply.

* Potential compatible uses are for illustrative purposes. The COE will determine the compatibility of specific proposed uses with the proposed Resource Use Plan.

* Existing uses are exempt from the Resource Use Plan plate. Revisions, expansions, and/or alterations to such "grandfathered" uses will be subject to COE review and approval.

V. PLAN IMPLEMENTATION

5-01 The Resource Use Plan provides a first step in the Federal review process for considering new development proposals within Prado Basin. Proposed uses will be reviewed for compatibility with the Resource Use Plan. After this initial review, a proposal will be reviewed specifically for adherence to the resource use objectives, compatibility with existing site features and for compliance with the National Environmental Policy Act. Additionally, the review process may require research into factors outside the scope of this study.

5-02 After the above mentioned review has been conducted, conflicts identified and resolved, COE staff will make a recommendation on proposed development on Federal lands based on the below mentioned review process criteria. This recommendation may approve, disapprove, or require modifications to the proposal (see fig. D-1).

5-03 County and city planning officials, in coordination with private developers when applicable, can utilize this process when making recommendations on proposed development on non-Federal land within the standard project flood zone of the basin, taking into consideration COE flowage easement restrictions.

5-04 The components of this review process are described as follows:

a. Resource Use Plan - The Resource Use Plan plate provides a key indicator in determining the compatibility of any proposed development, and provides the basis for preliminary review. The Plan is presented in Chapter 4. The Plan plate indicates types of uses that are compatible with biological and cultural resources and flood inundation restraints on development. Table D-3 provides potential compatible uses for each land use category. The Plan is based on two factors:

(1) Resource Elements - This study identifies six important resource elements: biological resources, cultural resources, soil erosion potential, topographic slope, visual quality and

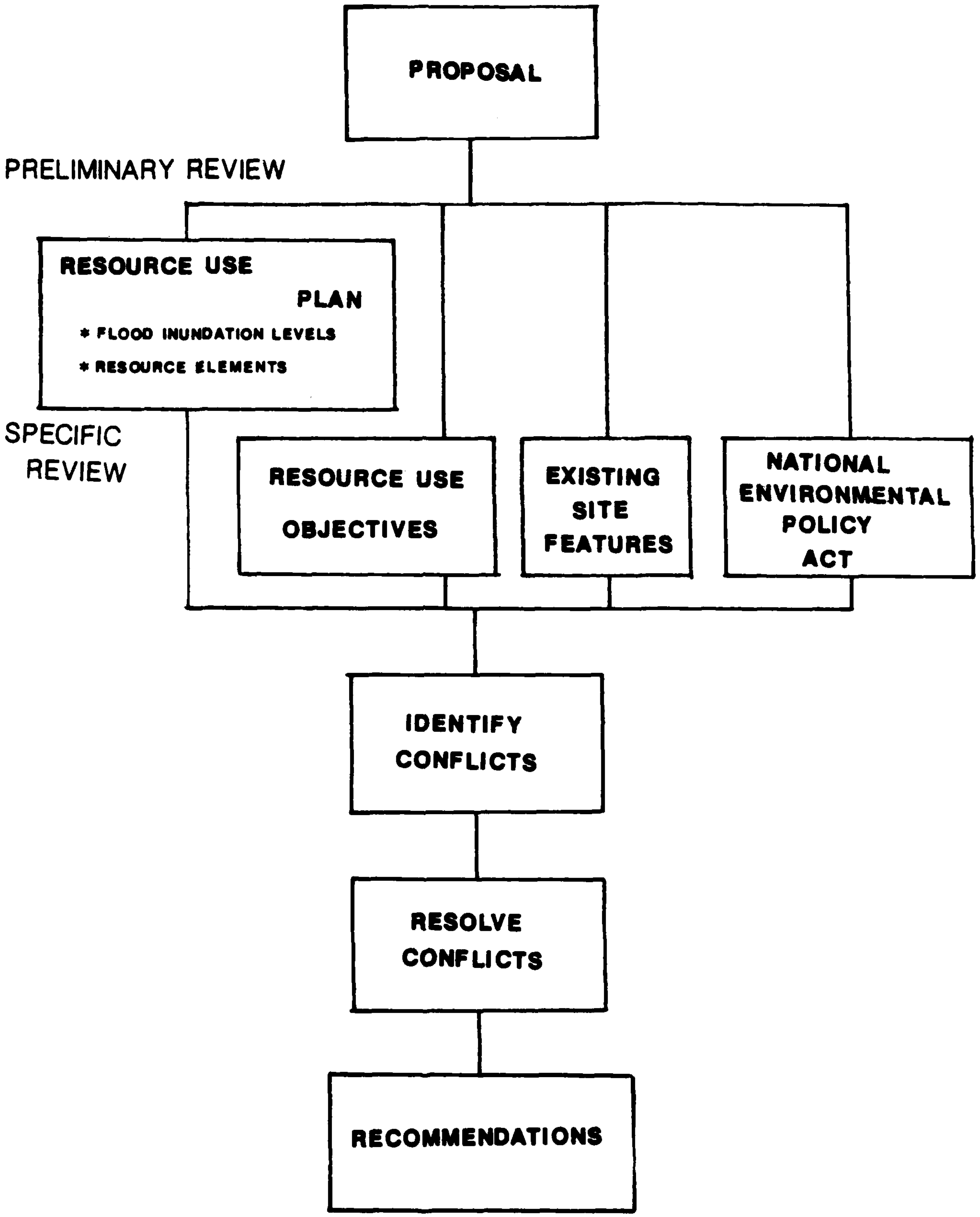
existing land uses. Biological and cultural resources serve as key elements in the overall Resource Use Plan. Detailed background information on resource elements is provided in Chapter 7.

(2) Flood Inundation Levels - Flood inundation levels are an important component of the Resource Use Plan. Based on the frequency of flooding, they provide development restraints, particularly regarding the location of structures. Detailed background information is provided Chapter 8.

b. Resource Use Objectives - The general and specific resource use objectives serve as a management tool in the review implementation process. They are intended to guide the design, appropriate use, and management of the basin's resources. The resource use objectives are provided in Chapter 6.

c. Existing Site Features - COE staff will utilize this data to further refine the review process in regards to potential conflicts with existing site features. Descriptions of the existing site features are given in Chapter 9.

d. The National Environmental Policy Act - Specific proposals for use or development will be subject to evaluation according to requirements of the National Environmental Policy Act of 1969.



REVIEW PROCESS
FIGURE D-1

VI. RESOURCE USE OBJECTIVES

6-01 The resource use objectives in this chapter are intended to serve as a management tool. The resource use objectives are to be applied when evaluating any proposed use of the basin.

6-02 Resource use objectives are intended to guide the design, appropriate use, development and management of the natural and other resources of the project to maximize benefits by meeting public needs and protecting and enhancing environmental quality. They are intended to provide a comprehensive approach to resource planning for the project rather than focus on detailed design or specifically on recreation potentials. This comprehensive approach permits flexibility for prioritizing and guiding design and planning decisions for the project. Management of the basin's resources consistent with established resource use objectives will help insure the preservation, conservation, and enhancement, and thus the future availability, of basin resources in balance with achieving the best and highest use of the basin.

6-03 These resources use objectives have been developed based on the process outlined in Engineer Regulation 1105-2-167 entitled "Resource Use: Establishment of Objectives".

6-04 The broader objectives consolidated in Chapter 3, were used in preparing the Resource Use Plan. The specific resource use objectives given in this chapter provide guidance for specific development.

6-05 A series of items have been identified as the essential general resources of the basin. The remainder of this section discusses each of these. For each item, a resource use objective has been developed, which is then followed by the specific resource use objectives for the particular item. A brief rationale supporting the objectives follows each item. Each of these items must comply with enviornmental laws and regulations and the flood control purpose of the basin. It should

be noted that resource use objectives are not priortized and some may in fact conflict. Conflicts will be resolved on a case by case basis.

Environmental Quality and Character

GENERAL RESOURCE USE OBJECTIVE

6-06 Protect and conserve the overall environmental quality and character of the basin, as well as the quality and character of the unique and important natural and cultural resources which comprise the basin.

Specific Resource Use Objectives

6-07 The following specific resource use objectives have been identified:

a. Encourage siting, design, and operation of facilities and activities to avoid or minimize adverse environmental effects.

b. Locate those activities which would have significant adverse impacts on the basin's unique or important natural and cultural resources in areas where such impacts would be avoided or minimized to a level of insignificance.

c. Encourage those uses, activities, and developments which conserve natural and cultural resources.

d. Preserve areas containing unique, sensitive, and/or significant resources so that they would not be disturbed and their inherent integrity and values would not be adversly impacted by other uses, management practices or development within the basin.

e. Require management practices for on-going uses, activities and developments that avoid significant adverse impacts to the basin's natural and cultural resources and the overall environmental quality and character of the basin.

f. Conserve those resources which cumulatively contribute to the basin's overall environmental quality and character.

g. Mitigate adverse environmental effects to the fullest extent practicable.

Rationale

6-08 Environmental quality and character refers to the integrity and value of a number of resources which comprise an environment, including ecological, esthetic, and cultural resources. The basin contains many

such specific resources which are considered important and/or significant. These resources individually and cumulatively contribute to the high overall environmental quality and character of the basin.

6-09 The preservation and enhancement of environmental quality is recognized as being of critical importance to overall human welfare and development. Through environmental legislation, Congress has indicated that protection and enhancement of environmental quality is in the public interest. The Federal Government recognizes this importance in light of past, and potential for future, profound effect of man's activities on the natural environment. Consideration of this, along with other essential considerations of national policy, is required in federal decision-making.

6-10 The resource use objectives detailed above are intended to respond to these Federal responsibilities. They have been formulated with the intent to achieve compatibility between the attainment of the widest range of beneficial uses of the environment and the protection and enhancement of environmental quality and a significant assemblage of resources for present and future generations.

Recreation

GENERAL RESOURCE USE OBJECTIVE

6-11 Develop a variety of recreation opportunities of a regional nature which will serve a broad cross section of socioeconomic needs.

Specific Resource Use Objectives

6-12 The following specific resource use objectives have been identified:

a. Provide low, medium, and high intensity recreation activities located in such a manner as to minimize impacts to the natural environment and conflicts between activities in the basin.

b. Provide self-supporting facilities and activities to serve the needs of the general public which will help offset operation and maintenance expenses associated with the overall operation of the basin.

c. Provide recreation opportunities that are available to a broad socioeconomic cross section of the region's population.

d. Provide safe and efficient circulation and access to the basin's recreation facilities in order to both control traffic and provide a linkage between the various activities within the basin.

e. Encourage local and regional planning efforts to coordinate the basin's facilities and resources with other recreation areas and facilities in the region.

Rationale

6-13 There is a critical shortage of open space within the urbanized Southern California region, which includes portions of San Bernardino, Riverside, Orange, and Los Angeles Counties. The basin offers a large area of open space and the potential for increased recreation opportunities in the heavily urbanized Los Angeles area. Due to the suitability of level sites for intensive recreation activities, a great deal of pressure to provide high intensity recreation activities may develop within the generally flat Prado Basin. Presently, the basin receives heavy regional use with a major portion (76 percent - 96 percent) of total use for Prado recreation facilities originating within a 30 mile radius of the basin. Heavy regional and local recreation demands will increase as development increases both in the immediate vicinity of the basin and throughout the entire region. Further development of recreation in the basin would help ease regional recreation demand pressures.

6-14 The basin is unique in Southern California in terms of its rich environmental resources, natural and pastoral quality and open space character. It contains extensive and productive riparian and wetland habitat which includes the largest stand of mature wooded wetlands remaining in Southern California. The basin provides an extremely important habitat for wildlife and provides the second most important migratory waterfowl habitat in Southern California. Prado Basin contains a unique preserve of highly signficant prehistoric and historic resources including a wide variety of historic sites and structures. It is essential that the development of recreation opportunities be in harmony with the natural and cultural resources of the basin.

6-15 Upon preliminary analysis, it appears feasible that the basin can support a variety of recreation uses, providing those uses are located and developed in a manner that will not negatively impact the natural environment. Methods of minimizing impacts include separation of incompatible activites, concentration of high intensity recreation activites away from low intensity passive and natural areas, buffering of higher intensity activities from less intense activities and suitability zonation of the basin based on natural and cultural resources preservation and land use compatibility.

6-16 In recent years, local agencies have been attempting to balance the costs of providing recreation services, through the development of self-supporting recreation activities. In order to maintain or decrease government expenditures, it is important to work toward regional self-sufficiency in terms of both providing facilities and paying for the development and upkeep of those facilities.

6-17 Prado Basin is an essential link in the recreational trail system planned for the Santa Ana River corridor from the Pacific Ocean to the crest of the San Bernardino Mountains in San Bernardino National Forest. Located at approximately the halfway point along the corridor and in combination with the Chino Hills State Park, the basin is intended to serve as a primary stopover and staging area for the trail system. The trail will primarily serve equestrians, bicyclists, and hikers and will tie into a number of local and community parks along the corridor. It is therefore extremely important that a well-planned interior trail and circulation system be developed which will complete and compliment the proposed system and provide and encourage access to it.

Education and Interpretation

GENERAL RESOURCE USE OBJECTIVE

6-18 Increase awareness and understanding of the basin's significant resources through educative and interpretive measures.

Specific Resource Use Objectives

6-19 The following specific resource use objectives have been identified:

a. Preserve areas for observation, research, and study of the basin's significant natural and cultural resources.

b. Provide and encourage educational and interpretive facilities where feasible.

c. Encourage improvement and development of activities, projects and programs for the basin that have educative and interpretive value.

Rationale

6-20 The basin is rich in natural, cultural and historical resources. Located in an area of increasing population and development, the basin is rapidly becoming a vestige of open space and riparian habitat in the region. Located in close proximity to the Los Angeles metropolitan area, the basin is accessible to a large and socioeconomically diverse population. The abundance of natural, cultural, and historical resources in combination with a large potential audience suggests numerous opportunities for educative and interpretive activities and facilities.

6-21 Development of educative and interpretive opportunities will serve not only to increase understanding of the basin and its resources but will also help to protect and preserve them. As the largest wooded wetland in Southern California, the basin's extensive wetlands provide habitat for hundreds of species of wildlife including several rare, threatened, and endangered species.

6-22 Currently there are no existing research-oriented ecological study areas within a 20-mile radius of the basin. Development of education and interpretive facilities and programs promotes visibility for the basin's resources which in turn may help promote public awareness and support of facilities, resources, and programs in the basin. The visibility provided by educative and interpretive amenities also may encourage volunteer, school and service organization involvement which can help preserve, develop, document, and enhance the basin's resources.

Open Space

GENERAL RESOURCE USE OBJECTIVE

6-23 Preserve open space to support and protect wildlife habitat, cultural resources, interim agricultural land uses, recreational land uses, and the environmental and visual character of the basin.

Specific Resource Use Objectives

6-24 The following specific resource use objectives have been identified:

a. Encourage continuing agricultural land uses as interim land uses which will provide open space and are consistent with preserving the rural and pastoral character and environmental quality of the basin and its environs.

b. Encourage interim agricultural land uses and practices which provide habitat, feed, and/or forage for wildlife in the basin.

c. Establish natural areas for the protection of rare and endangered species of flora or fauna, scientific, historical, archeological or visual values.

Rationale

6-25 Open space in the Southern California region and specifically in the area around Prado Basin is dwindling in supply as development occurs. The Chino Hills area, adjacent to the basin, is to provide almost 80,000 new dwelling units with an anticipated population of nearly 200,000 in the near future. Other areas in the immediate vicinity of the basin are developing as well.

6-26 Currently, the basin represents a primary source of open space in the region. The basin has a long-standing tradition of agricultural use, containing many dairies, ranches, and farms within the 566' elevation take line. Agricultural land use, the representative open space, has been mainly open field feed crops. The Soil Conservation Service has identified 5,146 acres as prime farmland in the basin below the 566' elevation, the majority of which is located in the upper basin near the fringes. Existing low intensity agriculture and natural areas

are generally land uses appropriate for preserving open space. Additionally, low intensity passive recreation activities and wildlife preserve areas are appropriate for preserving open space. The existing rural character of the basin is considered to be a highly important environmental quality to preserve in the region. Preserving agricultural land is also supportive of preserving and enhancing wildlife by providing feed, forage, and habitat for wildlife, and is a cost efficient way of preserving cultural resources.

Commercial and Industrial Operations

GENERAL RESOURCE USE OBJECTIVE

6-27 Provide opportunities for commercial and industrial operations in the basin.

Specific Resource Use Objectives

6-28 The following specific resource use objectives have been identified:

a. In cooperation with appropriate Federal agencies, manage commercial and industrial operations in a manner that will help offset public sector expenditures for operating and maintaining the basin.

b. Prohibit further expansion and promote the phasing out of existing land uses that deteriorate environmental quality and character without providing the least commensurate environmental compensation.

c. Minimize conflicts associated with existing land uses and activities through buffering, screening and other measures.

d. Manage real estate leases in the basin, in coordination with other Federal agencies, in a manner that will minimize surface resource use conflicts.

e. Minimize to the greatest degree possible traffic conflicts in the basin by separating heavy equipment and truck transportation associated with commercial and industrial operations, from other activities and transportation functions.

Rationale

6-29 General, there are very few commercial or industrial activities existing in the basin. Examples of such existing activities include those associated with oil and other resource extraction. Activities such as oil, sand, gravel, and silt extraction may be suitable within

the basin due to their support of national economic development goals or objectives intended to help offset operation and maintenance expenses for the basin. It should be noted that various overlapping government jurisdictions (such as the Bureau of Land Management (BLM) which manage gas and oil leases) require coordination with the COE within the basin.

6-30 Certain land uses may be impacting in terms of noise, air, water, and visual quality. Such uses should not be permitted to expand without the provision of offsetting compensation, and they should be mitigated to the greatest degree possible through buffering, screening, visual blending and other measures.

6-31 Due to the presence of oil equipment vehicles and other large vehicles, provisions should be made to provide safe and efficient traffic circulation within the basin. Unsafe conditions can result from conflicts between large vehicles and automobiles, bicycles, equestrians and pedestrians unless conflicting uses can be separated to the greatest degree possible.

Energy Resources

GENERAL RESOURCE USE OBJECTIVE

6-32 Increase regional energy self-sufficiency and the efficiency with which energy is used in the basin.

Specific Resoure Use Objectives

6-33 The following specific resource use objectives have been identified:

a. Maximize the efficiency with which energy is used for all existing and new land uses and activities in the basin through maximizing applications of energy conservation and renewable energy.

b. Minimize the use of non-renewable energy through energy efficient land use planning and construction technique.

c. Provide for the development of energy resources within the basin consistent with promoting national economic development.

Rationale

6-34 National and regional policies stress the continued importance of increasing energy self-reliance both at the national and local levels. Due to spiralling costs of non-renewable energy conservation and renewable energy resources has increased greatly over the past decade. Projections indicate that energy costs will continue to rise over the long run despite short-term price fluctuations.

6-35 As conventional energy costs rise, the economies of conservation and renewable energy sources grow increasingly more attractive. Applications of renewable such as solar, wind and microhydro can reduce needs for expensive new transmission lines and facilities which could be more visually and environmentally disruptive to Prado Basin. Land use planning, facility layout, and circulation design have a tremendous effect on energy consumption.

6-36 The greater the variety of services provided locally and the more attractive those services are, the less automobile driving is required for these services. This applies not only to commercial services but to recreation opportunities as well. Providing water conserving plumbing features and energy efficient insulation, building orientation, and site design, contributes to overall energy use reductions as well. Additionally, renewable energy applications make excellent public demonstration projects which aid public information dissemination, improve public relations, and help attract use of other local recreation and interpretive facilities. Finally, because the basin contains active oil wells and leases, the production of oil should continue until all concerned Federal agencies determine oil production in the basin is no longer necessary and agree to its phasing out or termination.

Water

GENERAL RESOURCE USE OBJECTIVE

6-37 Prevent further degradation of and, if possible, improve water quality within the basin and investigate the basin's potential role for increasing the efficiency of regional water use.

Specific Resource Use Objectives

6-38 The following specific resource use objectives have been identified:

a. Prohibit any activities in the basin, which serve the decrease the surface or ground water quality of the basin.

b. Investigate potential methods of maximizing regional water conservation and encourage implementation of water conservation improvement measures.

c. Investigate methods of improving regional water quality and encourage implementation of regional water quality improvement measures.

Rationale

6-39 Of the numerous issues confronting Southern California, the supply and efficient use of water is one of the most important. A number of factors contribute to the concern for water conservation including: the

region's dry climate; increasing development of streets, structures, and other impervious surfaces particularly on ground water recharge zones; the increased pumping of ground water; increasing costs of transporting water; building new water conveyance systems and maintenance of systems; increasing electricity costs for pumping water; continuous failure of ballot measures to deliver Northern California water; and recent court decisions limiting supplies of Colorado River water. There has been local interest expressed in water conservation as one aspect of water efficiency improvement.

6-40 This alternative should be evaluated along with numerous other alternatives for increasing water efficiency available for the region. It should be noted that operating the basin for water conservation may have significant impacts on the environmental quality and character as well as recreation and other uses of the basin. These impacts must be evaluated in order to determine the real costs and benefits of operating the basin for water conservation and to determine needs and opportunities for mitigation of impacts.

6-41 The predominate effects on water quality come from outside the basin although water quality affecting sources do exist within the basin. A number of factors contribute to the basin's degraded surface water quality including release of treated sewage effluent, runoff from the numerous dairies and farms, and residential development in the area. The predominate effects from outside the basin on water quality at Prado come from wastewater treatment plant releases into the Santa Ana River and Runoff from residences and farms in the Santa Ana River's large drainage area. Increased residential development will increase the concentrations of pesticides, fertilizers, and oil in the storm runoff. Periodic surface storm runoff can contribute to improving ground water quality by diluting current high levels of dissolved solids. Though the quality of Prado Basin's surface water contains high levels of total dissolved solids and other pollutants, it does support significant wildlife and vegetation.

Soil Resources

GENERAL RESOURCE USE OBJECTIVE

6-42 Conserve soil resources within the basin.

Specific Resource Use Objectives

6-43 The following specific resource use objectives have been identified:

a. Decrease soil erosion associated with existing conditions in the basin.

b. Minimize soil erosion within the basin for new condition in both the construction and post construction project phases.

c. Manage land use activities in a manner that optimize vegetative cover in order to minimize soil loss in the basin.

d. Encourage best management practices in land development, agriculture, and grazing activities.

Rationale

6-44 Erosion of soil due to turbidity can be a major contributor to silt and sediment deposits and thus to increased maintenance costs within the basin and downstream. Soil erosion may be the result of land development activities, grazing or agricultural practices. Numerous methods may be employed to decrease soil loss. Land use practices and both post- and during-construction practices can be adjusted to decrease soil loss.

Air Quality

GENERAL RESOURCE USE OBJECTIVE

6-45 Manage the resources, activities, and land uses within the basin in a manner that will not further degrade the air quality both within the basin and in the surrounding region.

Specific Resource Use Objectives

6-46 The following specific resource use objectives have been identified:

a. Preserve existing vegetation and encourage new planting of vegetation that preserves and improves air quality in the basin and surrounding environs.

b. Prohibit new land uses and activities in the basin that serve to deteriorate air quality unless impacts of those activities can be at least equally offset through implementation of measures to improve air quality.

c. Decrease air quality degradation from existing land uses and activities in the basin.

Rationale

6-47 Air pollution is a major problem in this portion of the south coast air basin. Temperature inversions restrict vertical dispersion of air pollution in the vicinity of the Prado Basin. Though little can be done to improve overall regional air quality, a number of possibilities exist for at least helping to maintain air quality in the basin and decreasing the contribution of pollutants dispersed to the region. Maintaining vegetation contributes to improving air quality by providing oxygen and by increasing the humidity levels in the air which has a purifying effect. Vegetation also helps filter out airborne particulates and reduce wind velocities which helps settle out particulates.

6-48 Erosion control practices also help reduce dust blowing into the air. Land use planning and efficient circulation design can less air pollution by restricting polluting land uses and by reducing automotive driving needs.

Esthetics

GENERAL RESOURCE USE OBJECTIVE

6-49 Preserve and enhance the rural, pastoral, open space, and natural esthetic quality and character of the basin.

Specific Resource Use Objectives

6-50 The following specific resource use objectives have been identified:

a. Minimize the adverse visual, olfactory, and noise impacts of new development activities within the basin.

b. Minimize existing visual and noise impacts within the basin.

c. Maintain esthetic surroundings at historic sites.

Rationale

6-51 The predominant land uses in the basin are dairying and grazing. Approximately 50 percent of the basin is covered with wooded wetland vegetation. The basin is considered an oasis of solitude and open space and a significant wildlife habitat area. The visual character of the basin may be described as rural or pastoral. As the most extensive wooded wetland area remaining in Southern California, the esthetics of the basin are of considerable importance as they represent a unique visual focus in the regional landscape. The extensive vegetation buffers noises of freeways and other activities surrounding the basin thus contributing to the overall peaceful character. Within this pastoral setting are found a variety of historical locations. The basin contains prehistoric sites, historic adobes, and other environmentally sensitive historic resources. Any new activities planned for the basin should reinforce the existing visual character through design that blends in form, line, color, and texture. Techniques for mitigating existing esthetic impacts regarding noise include buffering, screening, and separation of activities.

Cultural Resources

GENERAL RESOURCE USE OBJECTIVE

6-52 Conserve cultural resources within the basin through preserving appropriate sites, providing interpretative opportunities, and by improving knowledge of these resources.

Specific Resource Use Objectives

6-53 The following specific resource use objectives have been identified:

a. Preserve appropriate cultural sites within the basin.

b. Maximize eduction and interpretation aspects of cultural sites within the basin while maintaining or upgrading the condition of the sites.

c. Maximize study and research opportunities for appropriate cultural sites within the basin.

Rationale

6-54 Prado Basin contains a unique preserve of cultural sites representing many major periods of California's history and prehistory. Many prehistoric sites representing Millingstone and Intermediate-period occupation are present, some of which date back to as much as 6000 years ago. Prado Basin contains the only known reserve of inland Millingstone sites in the Los Angeles area. Other prehistoric sites representative of later periods are also present. Additionally, a number of historic Sites, representative of the Mexican and the American Agrarian periods are present in the basin. Certain properties lend themselves to interpretive programs while some sites, such as cemeteries, should be considered off-limits to any development. Appropriate sites should be preserved for future generations and advances in archeological knowledge and technicques. All cultural sites in the basin will require measures to protect them from vandalism.

6-55 In accordance with the National Historic Preservation Act, the Archeological Resources Protection Act, and Executive Order 11593, the Los Angeles District of the Corps acts as conservator for the nation for cultural sites within the basin. These properties are fragile and non-renewable. Significant cultural resources warrant protection whenever feasible. The Arecheological Resources Protection Act requires a permit for anyone wishing to conduct research.

Wildlife

GENERAL RESOURCE USE OBJECTIVE

6-56 Protect, maintain and, where possible, enhance wildlife resources.

Specific Resource Use Objectives

6-57 The following specific resource use objectives have been identified:

a. Maintain, and where possible increase the existing wildlife species diversity and abundance in the basin.

b. Protect, and where possible enchane habitat for rare, threatened and endangered species of wildlife within the basin.

c. Preserve significant and sensitive wildlife habitat, particularly transition zones and edges between vegetative communities.

d. Manage resources within the basin in a manner that will maintain or preserve the quality of wildlife habitat.

Rationale

6-58 One of the most important resources of the basin is its extensive and productive wooded wetland habitat. The basin contains the largest stand of mature wooded wetlands remaining in Southern California. These wetlands are comprised mostly of willows with occasional cottonwoods and sycamores. The extent of the basin and its relatively limited public access contribute to the important habitat values for resident and migratory bird species. Only the Salton Sea provides a larger, high-quality habitat for migratory waterfowl along the pacific flyway in Southern California. The basin also provides a permanent residence for various species of herons and flycatchers and numerous species of raptors and perching birds.

6-59 The areas of greatest wildlife value, in terms of species diversity and productivity occur at the edges or ecotones where different vegetative communities converge. These include the interfaces between wetland and open water communities and wetland and upland grasslands or agricultural areas. Some of the species of concern that utilize the Prado Basin are the least Bell's vireo, yellow-billed cuckoo, peregrin falcon, and bald eagle. The bald eagle, least Bell's vireo and peregrine falcon are listed on Federal and State endangered species lists. The yellow-billed cuckoo is a Federal candidate subspecies and is listed as rare by the State. A number of Federal laws provide direction for the protection of fish and wildlife.

Vegetation

GENERAL RESOURCE USE OBJECTIVE

6-60 Preserve and enhance vegetation in the Prado Basin.

Specific Resource Use Objectives

6-61 The following specific resource use objectives have been identified:

a. Protect and enhance rare, threatened, and endangered plant species.

b. Protect and enhance vegetation within the basin that is essential for maintaining the diversity and abundance of wildlife species within the basin.

c. Preserve and enhance communities of significant and sensitive wetland, and upland vegetation, and the transition zones between vegetative communities.

Rationale

6-62 Vegetation is essential for maintaining the diversity and abundance of wildlife species currently found in the Prado Basin. Wildlife protection and enhancement can best be accomplished by protecting and enhancing the various vegetation communities and the interfaces between them. The vegetation of the basin is a primary factor contributing to the visual quality and open space character. Maintenance of vegetation in the basin is essential for helping to control soil erosion and noise. Vegetation also contributes to microclimate control and control of air pollution and water quality. Stands of native vegetation are becoming scarcer in the vicinity of the basin, thereby increasing the importance of vegetation in the basin. Wooded wetland vegetation is particularly scarce in southern Claifornia. This continuity and extensiveness of this vegetation type in the Prado Basin are critical elements to its importance.

VII. RESOURCE ELEMENTS

7-01 Six resources within Prado Basin (biological, cultural, topographic slope, soil erosion potential, visual quality resources and existing land uses) serve as determinants in the review of proposed uses. The plates accompanying this section reflect each resource's sensitivity value as related to potential physical change with the exception of existing land uses. Existing land uses were directly incorporated into the Plan plate. Four categories of land use were developed to parallel these sensitivity values. Each land use category (number 1 through 4) reflects an increasing intensity of use and potential disturbance to a resource as noted in table D-4. Thus, the resource sensitivity values reflect the ability of each resource to accept a particular land use with minimal adverse effect to the resource. Table D-5 displays the categorization of each resource's sensitivity value specific to the appropriate land use classification.

7-02 Three of the resource elements, biological, cultural and existing land uses, serve as key determinants in the Plan plate; however, all six resources will be used in the review of proposed land uses for the basin. This will aid in preliminary determination of whether resources will likely be affected by proposed uses. For example: individual resource elements can be referred to in determining each resource's sensitivity to change as related to a specific land use proposal. Additionally, preliminary determinations may be made as to whether a specific area is sensitive in regards to soil erosion potential, topographic slope, and visual quality. Such sensitivities could require further research as to needed mitigation measures. High erosion potential, could, for example, require temporary and/or permanent soil stabilization measures such as temporary vegetation of slopes, sandbagging, and careful planning to correctly direct surface run-off.

Table D-4. Land Use Compatibility with Resource Value Sensitivity.

Land Use Category	Potential Compatible Uses	Resource Value Sensitivity
1	Fish and Wildlife Managemnt Cultural Resource Management Limited Hiking Interpretation/Education Limited Equestrian Trails	Extreme
2	Open space and low intensity uses that maintain resource values	High
3	Low Density Development of: Casual, Informal Play Areas Camping Picnic Areas Interpretive Structures Equestrian Trails Bicycle Trails Golf Courses Agricultural Lands Hiking	Moderate
4	Higher Intensity Developments such as: Boat Launch Swimming Beach Visitor Center Sports Fields Equestrian Center	Low

NOTE:

1. Table indicates lowest numbered land use category in which uses may be compatible (i.e., trails may be acceptable in category 1, 2, 3, and 4 areas but interpretive structures may be acceptable only in category 3 and 4 areas).
2. Site and proposal specific evaluation must still occur to determine acceptability of specific proposals.
3. List of uses is not all inclusive and serves as a guideline for COE review and use.

Table D-5. Resource Elements - Land Use Matrix.

	Resource Sensitivity Values			
Resource Elements	Extreme	High	Moderate	Low
Biological Resources	Resource Protection Areas	Resource Maintenance Areas	Moderate Resource Value Areas	Depleted Resource Areas
Cultural Resources	Preservation Areas	Significant Sites	Non-significant Sites	All Other Areas
Soil Erosion Potential	----	High	Moderate	Low
Topographic Slope	----	Greater than 15 percent	3 to 15 percent	0 to 2 percent
Visual Quality	----	High	Moderate	Low
	#1	#2	#3	#4
	Land Use Categories Compatible with Resource Sensitivity Values			

Biological Resources

7-03 Biological resources encompass those natural elements in the basin which are necessary and/or supportive to the maintenance and enhancement of vegetation and wildlife.

7-04 The biological resources plate (pl. 2) displays four levels of sensitivity. The description of each category and it's potential compatibility to development intensities follows. (Note: The compatible land uses cited for this resource serve an illustrative purpose. Refer to Chapter 4 for potential land uses suitable for Prado Basin.)

7-05 The following levels of sensitivity have been identified:

a. Extreme: Resource Protection Areas - Resource Protection Areas have an abundance of significant biological resources and/or a highly significant biological resource. These areas are capable of sustaining riparian habitat, which can potentially be habitat for the endangered least Bell's vireo. Certain areas within this designation are currently occupied by the least Bell's vireo. Continuity and extensiveness are important characteristics of most of the area mapped in this category. The prime objective in these areas is to maintain or enhance biological values. No adverse impacts, other than those due to flood control and possibly other future authorized purposes, are acceptable in these areas. Most of the basin's wetlands fall into this category. Compatible (1) land uses are activities which preserve and/or enhance biological resources. Some management may be necessary to maintain the compatibility of some activities on a site-specific basis.

b. High: Resource Maintenance Areas - Resource Maintenance Areas have important existing biological resources, and/or they are contiguous with Category 1 areas and serve as important buffers. Biological values will be at least maintained in these areas. Highly productive upland areas, as an example, belong in this category. The compatibility of activities would depend upon the resource of concern at specific sites. Activities with minimal impacts, such hiking or trailside interpretation would be compatible with this category in most cases. Existing parks and agricultural fields, for example, can also fall into this category where open areas are needed to buffer areas with extreme sensitivity. This is not meant to imply, however, that buffer areas are all potential parklands. On the contrary, it is desirable to maintain these buffer areas in as natural a state as possible.

c. Moderate: Moderate Resource Value Areas - Moderate Resource Value Areas have less diverse resource values but include important habitats, such as raptor foraging areas. Resource values should be maintained, but some degradation of these areas may be acceptable. Activities with moderate impacts, such as walk-in picnicking and camping and interpretive structures, would be compatible uses of these areas. Agricultural activities, particularly grazing, and golf courses are examples of other uses that could be compatible with some Moderate Resource Values on a site-specific basis.

d. Low: Depleted Resource Areas - Depleted Resource Areas have minimal biological resource values. These areas are generally scattered around the fringes of the basin and are often occupied by, or adjacent to, existing high intensity uses. Recreation activities with the greatest environmental impacts (e.g., those requiring structures and large parking lots) would be compatible with the resources in these areas.

7-06 A construction mitigiation area will be identified to mitigate all adverse effects to the basin as a result of the new flood control construction in the basin. Upon completion, this area will have been developed into a least Bell's vireo habitat area, requiring minimal disturbance.

7-07 A Waterfowl Management Plan for Prado Basin is being initiated in 1988 by the COE. Evaluations of proposals for development in the basin should include a review of that document, when it is completed.

Cultural Resources

7-08 Cultural resources refers to the numerous historic and prehistoric sites within Prado Basin. Site ages range from the Millingstone and Intermediate-period occupation to later periods including the Mexican and American Agrarian periods. As stated in the Resource Use Objectives (Chapter 6), the Corps of Engineers, Los Angeles District acts as conservator for the nation for cultural sites within the basin.

7-09 Cultural resources were categorized into four levels of sensitivity. The description of each category and its specific compatibility to development intensities is described below. (Note: The compatible land uses cited for this resource serve an illustrative purpose. Refer to Chapter 4 for potential land uses suitable for the basin. This report does not contain the cultural plate due to the site sensitivity and potential vandalism if identified.)

7-10 The following levels of sensitivity have been identified:

a. Extreme: Cemeteries - No development will be allowed in these areas. Extreme: Preservation Area - Low intensity development can be allowed in these areas, but only if in character with the cultural site (i.e., development would not affect the site or any development directed toward interpreting the site for the public). Sites in this category include those with high public interpretive potential and the most significant prehistoric sites. Also included are sites which are infeasible to mitigate. Small scale interpretive developments, educational uses, and scientific studies at these sites are encouraged. Any such uses however, may require mitigation of impacts.

b. High: Significant Sites - Development will be allowed pending adequate mitigation of impacts. This category includes both prehistoric and historic archeological sites and some historic structures. Proposed developments should attempt to design around or limit impacts to these resources. Any resulting impacts to these sites would be mitigated through data recovery, recordation, and/or documentation.

c. Moderate: Non-Significant Sites - Although there is no restriction on development in these areas, all grading operations would be monitored by a qualified archaeologist.

This category includes known cultural sites which do not qualify as significant sites based upon currently available data. The monitoring constraint is intended to ensure that any subsurface archeological deposits which are uncovered can be evaluated and mitigation measures taken, if appropriate. If such a deposit were discovered, the COE shall be contacted immediately to assess the significance of the find and take appropriate steps.

d. Low: All Other Cases - There is no constraint on development throughout the rest of the basin. However, all approved projects will include the provision that should presently unknown archeological deposits be unearthed during project planning or construction, the COE shall be immediately notified. The COE will assess the significance of the find and will develop any appropriate mitigation.

Topographic Slope

7-11 Topographic slope indicates the elevation change over a linear distance. Slope often serves as one determinant in the suitability of land uses.

7-12 The topographic slope plate (pl. 3) depicts three categories of slope. Each category will accept particular uses without the need to greatly alter the existing slope conditions. (Note: The compatible land uses cited for this resource serve an illustrative purpose. The sensitivity values of this particular resource closely align with the land uses determined to be compatible with the sensitivity values of the biological and cultural resources.)

7-13 The following levels of sensitivity have been identified:

a. Extreme: No land within the basin was identified in this category.

b. High: Steeper than 15 percent - Slopes steeper than 15 percent occupy a small portion of the basin. The bordering hills on the east and minor fringe areas within the basin have slopes of this category. Land uses suitable to such areas do not require large open and flat areas. Such uses include wildlife habitat and interpretive trails.

c. Moderate: 3 - 15 percent - Moderate sensitivity reflects slopes within the 3 to 15 percent category. Such slopes will accept a large number of uses without the need of altering the present landforms. Such uses include: bicycle and equestrian trails, casual and informal play areas, golf courses, and agriculture.

d. Low: 0 - 2 percent - Slopes from 0 to 2 percent readily accept the greatest intensities of uses, due to a minimum need to create large open buildable areas. Such areas can include recreation sports fields, building complexes and marinas. The majority of the study area falls within this category.

Soil Erosion Potential

7-14 Soils and their related area, steepness, length, vegetative cover, etc., have varying levels of potential for erosion. Utilizing the capability classes, subclasses, and descriptions provided by the Soil Conservation Service, the appropriate erosion potential for each soil phase (mapping unit) was identified on soil maps. The classification of areas as having high potential erosion does not prohibit development, but does serve as an early warning that specific site development mitigation measures will be needed to negate or minimize erosion. Such measures include temporary and permanent erosion controls such as sandbagging to direct drainage and the revegetation of exposed soils to provide temporary or permanent cover. The requirement for such mitigation will vary dependent on the sensitivity level of the respective area identified as well as specific site conditions. Plate 4 illustrates the interpretations for soil erosion potential. (Note: The compatible land uses cited for this resource serve an illustrative purpose. The sensitivity values of this particular resource closely align with the land uses determined to be compatible with the sensitivity values of the biological and cultural resources.)

7-15 The following levels of sensitivity have been identified:

a. Extreme: No land within the basin was identified in this category.

b. High: Soils within the northwest portion of the study area have the greatest potential for erosion. Soils with high erosion potential are within capability subclass "e" and a capability unit of "1". Furthermore those capability units containing descriptions of existing erosion or high erosion potential are contained in this sensitivity level. (Note: The letter "e" in a capability subclass indicates that the main limitation is the risk of erosion. Capability units (soil groups within subclasses) with the arabic number "1" indicate a soil group that has an actual or potential erosion hazard. Refer to Table D-6 for the actual classification.

c. Moderate: Moderate soil erosion potential areas occupy the upper northeast and southeast areas of the basin. Such areas have potential erosion characteristics as defined by a capability subclass of "e" or a capability unit of "1".

d. Low: Low soil erosion potential areas occupy the majority of the shallow areas within the basin. Soils within this category area soils excluded from the classifications above.

Table D-6. Capability Units Classified by Soil Erosion Potential.

Capability Unit	Pertinent Remarks	Erosion Potential Ranking
I - 1 (19)	----	M (Moderate)
I - 1 (20)	----	M
IIe - 1 (19)	Many soils eroded	H (High)
IIe - 1 (20)	Eroded	H
IIe - 4 (19)	Eroded - Water erosion not a hazard	M
IIe - 5 (19)	Erosion hazard - Slight to Moderate	M
IIs - 4 (19)	Erosion hazard - slight	L (Low)
IIs - 8 (19)	----	L
IIIe - 1 (19)	Many soils eroded or severely eroded - Erosion hazard - Moderately high	H
IIIe - 1 (20)	----	H
IIIe - 3 (19)	Erosion hazard - Moderate	M
IIIe - 4 (19)	Water erosion - Not a hazard	M
IIIe - 5 (19)	Erosion hazard - Moderate	M
IIIe - 6 (19)	Erosion hazard - Slight to Moderate	M
IIIe - 8 (19)	Some soils eroded	M
IIIw - 4 (19)	----	L
IIIw - 5 (19)	Erosion not a hazard	L
IIIw - 6 (19)	Erosion not a hazard	L
IIIs - 0 (19)	----	L
IIIs - 3 (19)	Erosion not a hazard	L
IIIs - 4 (19)	Water and wind erosion hazard is slight	L
IIIs - 4 (20)	Erosion hazard - Slight to Moderate	M
IIIs - 6 (19)	Erosion hazard - Slight	L
IIIs - 8 (19)	Erosion hazard - Slight	L

Note 1: e = Main limitation risk is erosion
1 = Actual or potential erosion hazard

Note 2: H = High erosion potential
M = Moderate erosion potential
L = Low erosion potential

Note 3: Refer to documents cited in text for specific soil/mapping units.

Table D-6. Continued

Capability Unit	Pertinent Remarks	Erosion Potential Ranking
IVe - 1 (19)	----	H
IVe - 1 (20)	Erosion principal hazard if soil cultivated	H
IVe - 3 (19)	Erosion hazard - High to very high	H
IVe - 5 (19)	Many soils eroded	H
IVe - 8 (19)	Most of these soils eroded erosion hazard is high	H
IVec - 1 (20)	Most areas eroded	H
IVw - 0 (19)	----	L
IVw - 6 (19)	----	L
IVs - 0 (19)	Erosion is not a hazard	L
IVs - 4 (19)	Clean cultivated soils; erosion hazard	M
IVs - 4 (20)	----	L
IVs - 6 (19)	Erosion not a hazard	L
IVsc - 4 (20)	----	L
VIe - 1 (19)	Eroded or slightly eroded	H
VIe - 1 (20)	Soils are eroded; slope erosion is principal hazard	H
VIe - 5 (19)	Erosion hazard is moderate	M
VIe - 7 (19)	----	M
VIe - 7 (20)	Soils eroded or severely eroded	H
VIe - 8 (19)	Soils eroded or severely eroded	H
VIec - 4 (20)	----	M
VIw - 1 (20)	Some soils eroded	M
VIs - 7 (20)	Erosion hazard is moderate	M
VIIe - 1 (19)	Soils are eroded or severely eroded. Erosion hazard - Moderate to very high	H
VIIe - 1 (20)	----	H
VIIe - 4 (20)	Soils are eroded	H
VIIw - 4 (19)	Subject to stream erosion	M
VIIw - 4 (20)	Steam Erosion	M
VIIs - 4 (19)	----	L
VIIIe - 1 (19,20)	Severe erosion	H
VIIIw - 4 (19,20)	----	L
VIIIs - 1 (19,20)	Severely eroded	H

Note 1: e = Main limitations risk is erosion
1 = Actual or potential erosion hazard

Note 2: H = High erosion potential
M = Moderate erosion potential
L = Low erosion potential

Note 3: Refer to documents cited in text for specific soil/mapping units.

Visual Quality

7-16 Mature vegetation and extensive open space typifies the visual character of Prado Basin, an area with land use devoted mainly to dairy farming and grazing. Undeveloped areas are covered with wooded wetlands, providing one of the major open spaces of this type in Southern California. In total, the basin represents a vast and unique visual resource in the region.

7-17 The intent in categorizing the basin's visual qualities is to describe units of landscape within the basin, displaying zones of quality intrinsic to a particular area's character.

7-18 Utilizing the aerial photo base supplemented with additional color and black and white aerials, the basin was classified into three land/visual quality patterns. The gradation of quality reflects the intensity of the mature vegetation patterns and the extent of open space; characteristics important to Prado Basin's visual quality. The visual quality levels indicate the highest ratings for those areas with the most "natural appearing" landscapes. Lowest rating reflects industrial uses. Thus, the sensitivity values, rate highest those visual types which reflect Prado Basin's overall rural and pastoral quality. Plate D-5 illustrates the interpretations for visual quality. (Note: The compatible land uses cited for this resource serve an illustrative purpose. Refer to Chapter 4 for potential compatible uses. The sensitivity values of this particular resource closely align with the land uses determined to be compatible with the sensitivity values of the biological and cultural resources.)

7-19 The following levels of sensitivity have been identified:

a. Extreme: No land within the basin was identified in this category.

b. High: "High" visual quality contains landscape units such as mature wooded wetlands, lakes, ponds, and natural appearing drainage courses. Development in such areas would require enhancement and perhaps extension of the specific area's visual character to lessen the obtrusive nature of a development. (Note: water bodies' and water courses' unit of visual quality extends 200 feet from the edge of the identified feature.)

c. Moderate: "Moderate" visual quality reflects areas of open space obviously altered for a specific use but where vegetation still dominates the visual character. Agricultural fields, dairies, and horse ranches serve as examples of such areas. Landscape areas in this category, while open to view, are compatible with high intensity, but visually sensitive, development due to the area's already altered character.

d. Low: "Low" visual quality areas include industrial land uses, extensive institutional uses such as prisons, and all other areas not previously categorized. Such areas would accept intensive

development without the potential harm to visual quality that other categories may reflect. The designation does not condone the introduction of poor visual quality elements, since any development within the basin should reflect sensitive esthetic concerns.

e. Additional Coding: In addition to displaying the various levels of visual quality, prominent roads which traverse or lay adjacent to the study area are also displayed. The locations of the roads is important since they provide views into the site to many travelers, perhaps providing interaction of site-to-user to the greatest number of people. The treatment of these edges (i.e., minimizing low quality views and emphasizing high quality views) will be of great importance to the land use planning within the basin. Furthermore, since the accompanying plate strives to provide a level of data compatible to the other resource elements, the analysis does not include visual items commonly found in more detailed studies. Such detailed studies serve site specific issues such as: the visual quality of individual elements (e.g., historical structures), the obtrusive nature of introduced elements (e.g., high power tension lines), and the locations of prominent views (e.g., viewshed mapping). All these items, while not specifically identified in this study, will be important to the more detailed proposal review process.

Existing Land Uses

7-20 The Prado Basin offers a large area of open space and the potential for recreation opportunities in the heavily urbanized Los Angeles area. The COE has a cooperative effort with both public and private sectors in the development of facilities within the basin. The basin also has a long-standing tradition of agricultural use, which consists of dairies, ranches and farms. Few commercial or industrial activities are located within the basin.

7-21 The primary purpose of the reservoir is flood control; all lessees, sublessees and property owners understand and have agreed in writing that their operation, facility or land is subject to periodic flooding. All of the land users within the basin fall into one or more of the five following categories:

a. Leases for parks and recreational purposes from the COE to Riverside County, San Bernardino County and the City of Corona. These leases allow concession agreements to third parties providing appropriate facilities and services to the public.

b. Land leased for parks and recreation purposes is leased from the COE for agricultural purposes until the land is needed for public use.

c. Various leases from the COE for special purposes such as sewage treatment plants and percolation ponds.

d. The Orange County Water District owns a large central section of the basin and leases the area for recreation purposes.

e. Oil and gas leases with the U.S. Bureau of Land Management, which controls subsurface mineral rights within the reservoir.

7-22 Within the context of the land uses noted above, the following is a brief description of the leases for use (Refer to pl. D-6 for location of noted land uses):

a. Tiro Shooting Range. This was the site of the 1984 Summer Olympic Shooting Venue. The facility is now open to the public and consists of approximately 40 acres; it contains stationary target shooting for pistols and rifles, an airgun hall and trap and skeet ranges.

b. El Prado Golf Course. This is a 36 hole (two separate eighteen hole) public golf course. The lease with San Bernardino County expires in 2015.

c. Prado Regional Park. This is a general use park open to the public. The park is approximately 260 acres in size.

d. Prado Recreation, Inc. This area is used as a dog training and boarding facility which is open to the public. The total leased acreage is approximately 507, of which 269 acres are in active use. The lease with San Bernardino County expires in 2001.

e. Prado Petroleum Company. This company operates oil and gas wells at low elevations within the reservoir. Three oil wells are leased through the Federal Government. The Government leasehold area is 195 acres. Ten oil wells are leased on Orange County Water District land. The private lease is known as the Santa Ana River Development Company (SARDCO) lease.

f. Raahague Duck Hunting Club. This area is a large waterfowl and pheasant hunting facility - for public use - located lower within the basin. The lands are leased from the Orange County Water District.

g. Splatter S. Duck Club. This is a 100 acre waterfowl hunting facility. The development consists of refuge ponds, shooting blinds and a barn-type structure. The lease with Riverside County expires in 1993.

h. Corona Airport. This is a recreational airport used mostly for small private planes; it is managed by the City of Corona.

i. Butterfield Park. This area includes ball diamonds, picnic areas and open play areas; it is managed by the City of Corona.

j. Corona Percolation Ponds. Land is leased by the City of Corona from the Federal Government for an effluent spreading area (ten ponds) and effluent pipeline and access road. The spreading grounds are designed to dispose five million gallons per day (mgd) of treated effluent.

k. Agricultural Leases. Areas within the three government leases are made available for agriculture until developed for recreational use.

l. Corona and Chino Treatment Plants. There are two sewage treatment plants within the basin. The City of Corona operates one and the other is managed by the Chino Sanitation District.

VIII. FLOOD INUNDATION LEVELS

8-01 The COE will not allow within Prado Basin any use which is contrary to the prime objective for the basin, i.e. the minimization of damage caused by flooding. To help achieve this objective, COE staff developed specific guidelines as to the placement and type of structures. These guidelines are based primarily on Federal regulations and simulated flood conditions for the basin. Flood proofed closed structures are delegated to the highest elevations, the areas of infrequent flooding. The lowest elevations, which contain the debris pool that will be subject to frequent flooding will not contain any structures.

8-02 Flood inundation levels reflect the debris pool, the 10, 50, and 100 year flood elevations, as well as the reservoir design flood elevation (pl. D-7). Additionally, the flood boundaries (100 year stream flows) and flood fringes (between 100 year and Reservoir Design Flood stream flows) are included for the Santa Ana River and Temescal Wash above the 100 year flood elevation. Flood fringes were determined using the flood boundary encroachment limit of one foot maximum allowable rise in water inflow elevation. This information is not necessary for Chino and Cucamonga Creeks, since they are channelized. The 100 year floodplains for the Santa Ana River, Temescal Wash, and Chino and Cucamonga Creeks are delineated below the 100 year flood inundation level extending to the debris pool (pl. D-7). Detailed analysis is necessary before locating any facilities in these areas since they are subject to change due to deposition and scouring. Plate D-7 corresponds to table D-7. Any proposed use is subject to the constraints listed under table D-7. Detailed hydraulic data is available at the COE, Los Angeles District office.

8-03 In addition to table D-7, the following restrictions will apply to development within Prado Basin:

a. Buildings for human habitation are prohibited below the guide acquisition contour line (566').

Table D-7. Flood Inundation Levels and Related Constraints to Improvements.

Inundation Levels	Title	Constraints	Potential Structures and Typical Land Uses
--- to 500	Debris Pool	Subject to prolonged flooding	No structures allowed. This area must be reserved in an open manner.
500 to 514	Debris Pool 10 yr. Flood	Subject to prolonged inundation	Structures are not recommended. Nature trails and open play fields are acceptable uses.
514 to 534	10 yr. Flood 50 yr. Flood	Subject to frequent flooding	Open-type or floodable structures and field facilities that can sustain inundation with acceptable maintenance costs from flooding. Concession stands with portable contents, bridletrails, shade and picnic ramadas, backstops, goalposts, etc., are considered appropriate.
534 to 550	50 yr. Flood to 100 yr. Flood	Subject to periodic flooding	Open-type floodable structures and multi-purpose paved surfaces that can sustain inundation with acceptable maintenance costs. Floodable restrooms are considered appropriate.
550 to 563 to 566	100 yr. Flood Reservoir Design Flood to Reservoir Take Line	Subject to infrequent flooding	Flood proofed closed structures are permitted. All appreciable structures will be approved by the COE's District Engieer.

Note: Land uses and structures acceptable at lower elevations may be developed at higher elevations. In areas with overlapping constraints, the more restrictive constraints apply.

Table D-7. (Continued)

Inundation Levels	Title	Constraints	Potential Structures and Typical Land Uses
Santa Ana River and Temescal Wash floodplains above the 550 elevation	Flood Boundary	Subject to frequent floodings	No structures allowed. This area must be reserved in an open manner to provide for the discharge of the base flood.
Santa Ana River and Temescal Wash floodplains above the 550 elevation	Flood fringe (between 100 yr. and Reservoir Design Flood stream flows)	Subject to variable flooding	Closed flood proofed structures are permitted along the floodway fringe. All development must meet Federal regulations and be approvd by the COE's District Engineer.
Santa Ana River, Temescal Wash, Cucamonga Creek and Chino Creek floodplains below 550 elevation	River Floodplains	Subject to frequent flooding	Open-type or floodable structures and field facilities that can withstand flood flow velocities, and will not impede the passage of flood flows. (Excludes area of Flood Boundary.)

Note: Land uses and structures acceptable at lower elevations may be developed at higher elevations. In areas with overlapping constraints, the more restrictive constraints apply.

b. All buildings or structures within the basin shall be of non-floatable material or anchored in such a manner to make them non-floatable when subject to inundation.

c. In no case shall the lands be used or made available for use for any purpose in conflict with the purposes for which the Prado Flood Control Basin was constructed.

d. When property in floodplains is proposed for outgrant or disposal to non-Federal public or private parties, the COE shall reference in the outgrant or conveyance those uses that are restricted under Federal, State, and local floodplain regulations and attach other restrictions to uses of the property as may be appropriate. In the event the proposed use is incompatible with good floodplain management, the COE shall consider withholding such properties from outgrant or conveyance.

e. Section 404 regulatory permits may be required for discharges of dredged or fill material into wetlands within the basin. The term wetlands refers to those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions.

f. Proposed development at Prado Basin must meet stringent environmental requirements. No structure or activity will be permitted on Federal land which will have serious adverse impact on the environment. Preference shall be given to uses which will preserve and promote recreation and fish and wildlife enhancement potential of the project or, in the absence thereof, will not detract from that potential.

g. Elevation 514' is the 10 year flood inundation level for Prado Basin under conditions for the All River Plan. Special attention should be given to any activities or facilities below this elevation as a relatively high frequency of flooding can be expected.

h. Consideration must be given to the development of any structure or facility with respect to the proximity of the streambeds of Chino Creek, Cucamonga Creek, Temescal Wash, and the Santa Ana River. During flood conditions, these areas will be subject not only to inundation by rising water but also to the velocity of the moving water.

i. Development is not allowed within flood boundaries.

j. Structures should be built so as not to impede the passage of floodflows. To achieve flood protection, agencies shall wherever practicable, elevate structures above the base flood level rather than filling in land.

8-04 The following definitions are presented for clarification and for use with the Plan:

a. Base Flood - That flood which has a one percent chance of occurrence in any given year (also known as a 100-year flood). This term is used in the National Flood Insurance Program to indicate the minimum level of flooding to be used by a community in it's floodplain management regulations.

b. Debris Pool - A pool of water normally established to provide sufficient water depth to fully submerge the outlet gates and to prevent vortex action from drawing floating debris into the gate openings. The debris pool also forms a still (zero velocity) body of water that stops the movement of heavy bedload material transported by the inflowing streams from reaching the outlet gates. When reservoir inflows begin, as a result of a significant period of rainfall, the debris pool is built up, and no major releases are made from the dam until the debris pool elevation has been reached.

c. Facility - Any man-made or manplaced item other than a structure.

d. Floodable Structure - A structure that is able to withstand structural loads due to 100-year flood conditions. Contents and interior finish materials are restricted to types which are neither hazardous nor vulnerable to loss under these conditions. Flood waters will be able to pass through these structures or these spaces will be flooded with flood water by automatic means. Vents will be provided to prevent the formation of air pockets.

e. Flood Fringe - That portion of the floodplain between the flood boundary and the standard project flood.

f. Floodplain - The lowland and relatively flat areas adjoining inland and coastal waters, and including, at a minimum, that area subject to a one percent chance of flooding in any given year.

g. Flood Proofing - A combination of structural changes and/or adjustments incorporated in the design and/or construction and alteration of individual buildings, structures, or properties subject to flooding primarily for the reduction or elimination of flood damages.

h. Open Structure - A structure which may or may not have a sealed roof, but does not have sufficient walls to obstruct the flow of flood waters.

i. Flood Boundary - The channel of a river or other watercourse and the adjacent land areas that must be reserved in an open manner

to provide for the discharge of the base flood. In this case, the flood boundary is the 100 year flood line.

j. The flood that will result in a maximum water surface equal to the spillway crest elevation (563').

k. Structure - Walled or roofed buildings, including mobile homes and gas or liquid storage tanks that are primarily above ground.

IX. EXISTING SITE FEATURES

9-01 Thirteen elements of existing land use or site features were identified for their potential importance to the Prado Basin planning and review process. These elements will be used to further refine the review process, especially in regards to potential conflicts with existing and future planning efforts.

Climate

9-02 The Prado Basin can be characterized as a "Mediterranean" climate, and is typified by warm dry summers and mild winters.

9-03 The mean daily temperature for the area is 62.9 degrees Fahrenheit with a mean daily maximum of 78 degrees Fahrenheit and a minimum of 47.9 degrees Fahrenheit. Low temperatures for the area occur during the months of December, January, and February. They have a mean daily average of 53.8 degrees Fahrenheit, 51.8 degrees Fahrenheit, and 53.4 degrees Fahrenheit respectively. Extreme high temperatures for the area have exceeded 110 degrees Fahrenheit, while extreme lows of 22 degrees Fahrenheit have been recorded.

9-04 Precipitation in the area occurs primarily during the winter months. The rainy season occurs from November thru April, while dry periods predominate throughout the balance of the year. Annual precipitation averages 12.76 inches.

9-05 Wind patterns across the south coastal region are characterized by westerly and southwesterly onshore winds during the day and easterly or northeasterly offshore breezes at night. Wind speeds are somewhat greater during the dry summer months than during the rainy winter season. Between the periods of dominant air flow, periods of air stagnation may occur during the morning and evening hours. Whether such periods of stagnation occur is of critical importance for air quality conditions on any given day.

9-06 Air pollution has long been a problem in the south coastal region of California. The most significant problems in the project area are with transported pollutants; especially ozone and suspended particulates. These pollutants are derived primarily from upwind vehicular sources in Los Angeles and Orange Counties. Since the project area is relatively undeveloped, mobile source pollutants generated on site are not a major contributor to local or downwind air pollution problems. A major feature of the area's climate is the temperature inversion that influences the vertical dispersion of air pollutants. Inversions occur when the air temperature increases rather than decreases with altitude. The combination of low wind speeds (averaging less than 15 mph) and a low inversion produces the greatest concentration of pollutants in the basin.

9-07 The climate element does not have an accompanying plate. The data is intended to be used as a general reference in the overall planning effort. Specific siting studies should reflect specific microclimatic conditions such as seasonal wind patterns and solar orientation.

Circulation

9-08 Major circulation routes, the Riverside Freeway (91) and the Corona Expressway (71) respectively, bound the south and west edges of Prado Basin as illustrated in plate D-8. Additionally, several major highways cross the basin in the northern areas. Secondary and collector streets primarily occur outside the basin's 566 take line.

9-09 The information displayed in plate D-8 reflects the combination of plans of several county and local jurisdictions. The information may not reflect strict definitions as defined by transportation planners/ traffic engineers. The intention is to exhibit the hierarchy of road types within the study area as either State highways, major highways or secondary/collector streets which may be used in specific siting studies to reflect access opportunities and constraints.

County and Local Zoning

9-10 Prado Basin is situated within the two counties of San Bernardino and Riverside as illustrated in plate D-9. The cities of Corona and Norco, within Riverside County, form and fall within the eastern boundary of the basin. The basin's primary zoned use is agriculture and open space. Some residential zoning does occur within the basin's 566 take line.

9-11 The zoning as indicated in plate D-9 can be used in specific siting studies to gain a general understanding of local planning directions. While the Federal Government is not required to comply with county and local zoning on lands owned in fee by the Federal Government, the zoning does apply to public and private lands on which the Federal Government has acquired flowage easements. This review will also make

apparent potential conflicts or items requiring further clarification. As zoning is a continuing and evolving process, appropriate agencies should be contacted to ascertain current land use/zoning designations.

9-12 County and local planning departments were contacted to obtain current zoning information and provided a review of plate 9. As each jurisdiction's classifications varied, they were aggregated to fall within several major land use designations which include commercial, institutional, mixed use, agricultural, industrial, residential and open space.

Surface Water Quality

9-13 The quality of water in the Santa Ana River in the vicinity of Prado Dam is directly influenced by the quality of the inflows into the area. The inflows include several tributaries (Cucamonga Creek, Chino Creek, and Temescal Wash), rising groundwater, municipal sewage effluent, and/or non-point discharges (urban and agricultural runoff). Although several of the mountain streams in the upper Santa Ana River watershed are perennial, all water flows in these streams is diverted for groundwater recharge purposes upstream of Prado. The inflow to Prado Basin remains perennial due to discharges from sewage treatment plants. The River below Prado may contain as much as 95 percent treated municipal effluent during dry weather flow. Below Prado Dam, the River is diverted for recharge of the Orange County groundwater basin.

WATER QUALITY CRITERIA AND MEASUREMENTS

9-14 In order to protect the quality of surface and groundwater in the basin, the Santa Ana Regional Water Quality Control Board (SARWQCB) established water quality criteria which should be maintained in order to protect the identified beneficial uses of the water and to prevent nuisance conditions from developing (i.e., algal blooms). The beneficial uses identified by the SARWQCB for the River in the vicinity of Prado Basin include: agricultural water supply, groundwater recharge, water contact recreation (i.e., swimming), non-contact water recreation (i.e., boating, fishing, picnicking), warm freshwater habitat, and wildlife habitat. With respect to these criteria and uses SARWQCB has identified the increasing amount of dissolved minerals in the groundwater and surface waters as the major water quality problem in the Santa Ana River.

9-15 Inflow water quality to Prado Basin is measured by the Orange County Water Control District (OCWD) at the following locations: Santa Ana River at River Road (at USGS gage), Chino Creek, Temescal Wash, Cucamonga-Mill Creek above sewage discharge, and sewage discharge to Cucamonga-Mill Creek. The OCWD also samples the outflow from Prado Basin on the Santa Ana River (at the USGS gage) on the same days that the inflow stations are sampled. Water, when impounded behind Prado Dam, is also sampled. Table D-8 contains average values of various water quality parameters for the inflow stations, outflow station, and for the occasional impoundments behind Prado Dam.

Table D-8. Average Values of Water Quality Parameters for Inflows, Outflow, and Impoundment: March 1982-February 1984.

	Flow (cfs)	TDS (mg/l)	SS (mg/l)	NO_3-N (mg/l)	Fe (ug/l)	Mn (ug/l)
Inflow						
SAR above Dam	240	536	210	5	121	78
Cucamonga-Mill Creek above Sewage Plant	19	647	42	2	209	107
Sewage Discharge to Cucamonga Mill Crk	5	459	8	5	17	16
Chino Creek	32	680	23	8	22	142
Temescal Wash	53	960	238	8	9	144
Outflow						
SAR below dam	360	577	76	4.5	218	139
Impoundment behind Prado						
Surface	---	480	4	3	108	91
Bottom	---	486	153	2	291	100

Source: Orange County Water Control District Unpublished Data.

9-16 These data suggest that the water quality of the inflows is variable and that elements of concern include total dissolved solids, nitrates, iron, and manganese. The primary factors controlling variability are inflows to the basin and impoundment of water. Temescal Wash contributes the highest concentrations of total dissolved solids (TDS) and total suspended solids (TSS) but the lowest concentration of iron (Fe). Chino Creek and Temescal Wash contribute the highest nitrate (NO3) and manganese (Mn) concentrations. This is significant because Temescal Wash has the highest average flow rate and thus has the greatest influence of all the tributaries on the water quality of the River below Prado Dam. On the average, the River below the Dam has higher concentrations of TDS, Fe, and Mn than it does as it flows into the basin. This is because of the influence of the tributaries flowing into the basin.

9-17 The United States Geological Survey (USGS), as part of the National Stream Quality Assessment Network, measures the quality of water released from Prado Dam. This sampling station is located just downstream of the Dam. Tables D-9 and D-10 contain average concentrations of twenty two water quality parameters. Approximately half of the samples exceeded the water quality objectives for TDS and sodium that were established by the SARWQCB. During the sampling period, nitrates exceeded the objectives once. The data presented in Table D-10 indicate the possible presence of a more serious problem. The data indicate that the potential exists for cadmium, lead, mercury, PCBs, and lindane to accumulate in freshwater organisms in the River. The California Department of Fish and Game (CFG) has been sampling fish in the River below Prado Dam and analyzing them for trace metals and organics. At present, the only measured parameter of concern for PCBs in the fish is still below the Food and Drug Administration warning level of five parts per million. The CFG is continuing to monitor the fish below Prado Dam to ensure that toxic levels of contaminants do not accumulate in the fish.

EFFECTS OF FLOOD CONTROL AND WATER STORAGE OPERATIONS

9-18 At most times during most years, water inflows are not detained in the basin, but pass immediately downstream, with little change in water quality except for that contributed by the inflows themselves. Impoundment of water occurs in the winter storm season for flood control purposes. This flood storage is also operated for incidental groundwater recharge downstream. Impoundment of water can lead to a variety of water quality problems, attributable to existing water quality and impoundment effects.

9-19 Impoundment of water for short periods of time, with rapid drawdown (as for normal flood control operations) has had little adverse effect on water quality. In fact, whatever effect may occur downstream would probably be beneficial, since flood waters containing a low concentration of TDS would dilute existing water containing a high concentration of TDS. The released water then percolates into the aquifer.

9-20 Extended impoundment, especially a substantial volume of water, would be more likely to result in adverse water quality effects. These could include stratification of the storage pool and associated anaerobic conditions. Anaerobic conditions may result in the release of undesirable products of anaerobic processes. These products, which include hydrogen sulfide, ammonia, iron, manganese, and reduced organic compounds, can produce toxicity, taste, odor, and staining problems in the basin and downstream. The extended evolution of hydrogen sulfide in impounded waters can also result in corrosion of the outlet structures of the Dam.

9-21 In addition, under anaerobic conditions, trace metals such as cadmium, lead, and mercury may be released from sediments. Local nuisance conditions, such as algal blooms and health hazards, such as mosquito breeding may also occur. Extended impoundment can also have beneficial effects on water quality. Included in this are the lowering of suspended solids and nitrate concentrations. Total dissolved solids can be reduced by dilution with flood waters.

Table D-9. Average Concentration of Water Quality Parameters at SAR below Prado, October 1979-September 1983.

Parameters	No. of Samples	Average Concentration or Values	California Drinking Water Standard	No. of Times Standard Exceeded	Water Quality Objectives	No. of Times Objective Not Met
Flow (cfc)	54	445	None	NA	None	NA
Specific Conductance	54	998	900[1]	36	None	NA
Dissolved Oxygen (mg/l)	41	9.0	None	NA	5	0
Sodium (mg/l)	50	94	None	NA	110	24
Sulfate (mg/l)	49	124	250[1]	0	150	11
Chloride (mg/l)	49	111	250[1]	0	140	10
Total Dissolved Solids (mg/l)	54	615	500[1]	39	700	22
Nitrate/Nitrate[2] (mg/l)	51	4.6	10	1	10	1
Total Inorganic[2] Nitrogen (mg/l)	51	7.1	None	NA	10	11
Iron[2] (ug/l)	24	29	300	0	1000[3]	0
Manganese[2] (ug/l)	23	186	50	20	None	NA
Total Phosphorus	49	2.1	None	NA	None	NA

Note: 1. Maximum recommended level.
2. Filtered.
3. EPA water quality criteria for protection of freshwater aquatic life.

Source: USGS, 1980, 1981, 1982, and 1983.

Table D-10. Average Concentrations of Trace Metals and Orangics at SAR below Prado, October 1979-September 1983.

	No. of Samples	No. of Times Detected	Av. Conc. of Detected Values	Calif. Drinking Water Standard	No. of Time Standard Exceeded	California Freshwater Aquatic Life Standard	No. of Times Standard Exceeded
Arsenic (ug/l)	24	24	5	50	0	440	0
Barium (ug/l)	25	23	126	1000	0	None	NA
Cadmium (ug/l)	19	12	3	110	1	.03-.2^1	12
Lead (ug/l)	24	23	34	50	1	5-323^1	X^2
Mercury (ug/l)	26	22	0.7	2	1	.2	13
PCB's (ug/l)	15	1	.1	None	NA	.01	1
Endrin (ug/l)	17	0	NA	2	0	.002	0
Lindane (ug/l)	17	13	.01	4	0	.01^3	5
Methoxychlor (ug/l)	17	0	NA	100	0	.03^3	0
Toxophene (ug/l)	17	0	NA	5	0	.01	0
2, 4, D (ug/l)	16	16	.11	100	0	None	NA

Note:
1. Depends on hardness of sample.
2. Impossible to determine without calculating the hardness of each sample.
3. EPA water quality criteria for protection of freshwater aquatic life.

Source: USGS, 1980, 1981, 1982, and 1983.

9-22 Water quality problems related to impoundments are exacerbated by long storage of deeper, more stable pools, especially over the summer months when higher temperatures facilitate stratification and anaerobic conditions. An appropriate example is the situation which occurred at Prado Basin during the summer of 1980. In that year, water was held over an eight month period, from February through September. The maximum water storage elevation that year was held to 503 feet. Some water quality measurements were taken by OCWD in July, after six months of impoundment. The water pool was found to be highly stratified, with anaerobic conditions in the bottom half of the storage pool. Although related data is not available, it must be assumed that many of the problems associated with anaerobic conditions also occurred. In 1983, water was again held to a high level for an extended period of time. Mosquito breeding and related health hazards were an additional problem that year. These situations, though serious, are infrequent and short-term in nature under current water storage operations.

9-23 Despite incomplete attainment of water quality criteria, the SARWQCB believes that the water quality at Prado Basin is suitable for the beneficial uses discussed above. In order to maintain or improve water quality in the River, the SARWQCB regulates discharges into the River. The Regional Board sets waste discharge requirements on point source discharges (i.e., sewage treatment plants). Nonpoint source discharges, generally urban and agricultural runoff, will be regulated by requiring compliance with Best Management Practices. In addition, the effect of rising groundwater on the water quality of the River will be reduced by the extraction of brackish groundwater in several sub-basins. On-going as well as proposed activities in the basin must take into consideration existing and potential water quality problems and the need for improvement in this area.

Prime and Unique Farmland

9-24 Prime and unique farmland depicts areas within the basin deemed to be of importance as defined by the Farmland Protection Policy Act of 1981. The purpose of the Act is to minimize the extent of the role of Federal programs in the conversion of farmland to non-agricultural uses and to assure that Federal programs, to the extent possible, are compatible to State, local and private farmland protection measures. While the purpose of the Act is to protect farmland, the Act does not require a Federal agency to modify a project solely to avoid or minimize the effects of conversion of farmland. Rather, the legislation requires that consideration be given to the effect of farmland conversion and to consider alternatives to lessen foreseen negative effects.

9-25 Agricultural use of project land is in no case an authorized project purpose but an interim or corollary use to maximize land productivity and/or to maintain open park-like areas consistent with the authorized purposes. Interim agriculture will be permitted when it is determined not to be detrimental to authorized purposes, recreation use

or wildlife habitat. The COE will take into consideration the stipulations of the Farmland Protection Policy Act in the specific site studies.

9-26 Plate D-10 documents four distinct categories of prime and unique farmland as interpreted for California standards. These include prime, statewide important, unique and locally important farmlands.

9-27 Prime farmland is land best suited for producing food, feed, forage, fiber, and oilseed crops. Said land is available for these uses. The land has a soil quality, growing season, and moisture supply needed to produce sustained high yields of crops economically and per modern farming standards.

9-28 Statewide important farmlands is available land, other than prime farmland, that has a good combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oil seed crops.

9-29 Unique farmland is land, other than prime and statewide important farmlands, that is currently used for the production of specific high value food and fiber crops. Such land has the special combination of soil quality, location, growing season, and moisture supply needed to produce sustained high quality and/or high yields of a specific crop when treated and managed according to modern farming methods. Examples of such crops are citrus, olives, avocados, fruit and vegetables.

9-30 Locally important farmlands and lands, while not of national or statewide importance, have local importance to the production of food, feed, fiber, forage, and oilseed crops. Such farmlands have significant community economic importance. A local agricultural committee organized by the Resource Conservation District provided definitions for these farmlands.

Geology

9-31 The geologic information as shown in Plate D-11 displays a variety of data including potential silt and clay borrow areas, landslides, and fault hazards.

9-32 The basin is composed of Tertiary, Miocene, and lower Pliocene age (10 to 25 million years old) sediments called the Puente formation. The sediments consist mostly of friable sandstones with hard siltstone and shale interbeds and scattered lenses of conglomerate. Uplift of the region occurred during the past two to three million years and deformed the Puente formation with extensive warping and faulting. Recent alluvium is present in the Santa Ana River channel and in the reservoir.

9-33 Four categories have been noted in plate D-11. These include sand and gravel, silt and clay, landslides and fault hazards. This information should be used in specific siting studies in addition to more site specific assessments.

9-34 Substantial areas within the Prado Basin are presently under consideration by the COE for borrow sites. These areas contain fine-grained sediments which could be utilized as construction material for raising the Prado Dam, as well as for the construction of several dikes at various points throughout the basin.

9-35 The proposed site in the northern portion of the basin is the most likely borrow site for dikes to be constructed around the California Institution for Women and the Corona Expressway (State Highway 71). The other proposed borrow sites, near the existing Prado Dam, are potential sites for the raising of the dam itself and building the auxiliary dike, as well as for the construction of dikes at the Corona Sewage Treatment Plant, Alcoa Aluminum Plant and the Corona National Housing Tract. Previously proposed borrow sites were less competitive due to such factors as groundwater, vegetation and soil composition and therefore were eliminated from further consideration. Borrow areas 1 and 2 as shown in the Geotechnical Appendix will be utilized during construction of the Prado Dam project features. Investigations of additional potential borrow areas is not planned.

9-36 Presently, four ancient landslides are recognized along the eastern slopes of the Chino Hills, which are located at the western edge of Prado Basin. These slides, which are outside the reservoir limits, are fairly limited in size, varying from 200-800 feet in width and 300-800 feet in length. The slide masses are located north of the proposed dike at the Corona Expressway. Possible reactivation of these landslides would not impact the dike structure. In addition, the dike alignment would minimize the potential for initiation of new slides.

9-37 The potential for movement on the Chino and Central Avenue Faults could affect land use in the southwest portion of Prado Basin. The Chino Fault has been historically aseismic, but because of its relationship with the Whittier and Elsinore Faults to the south and the regional tectonic setting, it should be considered potentially active. For design purposes, the San Andreas and Whittier Faults were selected as the regional and local faults, respectively, capable of producing earthquakes which would generate the strongest shaking at the project site. The Central Avenue Fault is also historically aseismic and is concealed at ground surface. Its tentative location is based on gravity and groundwater anomalies. Special restrictions on development near the concealed trace of the Central Avenue Fault are not warranted at this time. Consideration should be given to the liquefaction potential of foundations for permanent structures because of the relatively high groundwater table, the alluvial nature of the basin fill, and the proximity of the basin to major active fault zones such as the Whittier Elsinore, San Jacinto, and San Andreas.

Oil and Gas Leases

9-38 Plate D-12 illustrates the location of oil and gas leases on COE land. There are seven leases currently issued, two of which contain producing wells.

9-39 Oil and gas leases are administered by the Bureau of Land Management with the concurrence of the COE. Two types of leases are granted. These include competitive and non-competitive leases. The difference between the two types of leases is that a competitive lease is issued on land within an area which has been identified as a known geologic structure (KGS). A non-competitive lease is not located within an identified KGS area.

9-40 There is one competitive lease in the project area. The initial lease period for a competitive lease is five years. If at the end of the five year period, drilling operations exist (no production yet), a two year extension is granted to bring the operation into production. Once in production within that two year period, the lease is extended indefinitely until such time as production stops. If the lease is already in production within the initial five year period, the lease is extended indefinitely until such time as production stops. The lease is then terminated and is again offered competitively.

9-41 There are two types of non-competitive leases. Areas that have been previously issued under a non-competitive lease are again offered for lease by means of a simultaneous oil and gas leasing system. Those areas that have not been previously leased are offered over the counter through an application process. There are currently six non-competitive leases in the area which have been granted through the simultaneous oil and gas leasing system. The same terms afforded to a competitive lease apply to a non-competitive lease with two exceptions. First, the initial lease period is ten years. Second, when a lease is terminated, it is again offered non-competitively through the simultaneous oil and gas leasing system.

9-42 Land currently owned by Orange County Water District was not reviewed for current oil and gas lease operations. Known oil and gas well locations on Federal land are displayed on the oil and gas well location plate.

9-43 Plate D-12 notes each lease area and whether producing wells currently exist on the property. Additionally, the plate identifies leases by their Bureau of Land Management Serial and Parcel Number.

Oil and Gas Wells

9-44 Plate D-13 illustrates the location and current well status of each well according to the California Division of Oil and Gas. In addition to specific identification numbers, the following well status designations are indicated: abandoned oil, completed gas, abandoned - dry hole, completed - oil and drilled - idle. This information should be taken into consideration in specific site studies to avoid potential siting conflicts with known well locations.

Master Recreation Outgrant Boundaries

9-45 Master recreation outgrant boundaries for San Bernardino County, Riverside County, and the City of Corona contain recreation outgrants and agriculture outgrants for the respective jurisdictions as indicated on plate D-14. Interim agricultural use is permitted where land is not presently needed for recreation purposes. Agriculture outgrants may revert back to recreation outgrants as needed. Specific site studies should take this information into account when siting either recreational or agricultural uses.

Recreation Outgrants/Ownership

9-46 Areas depicted on plate D-15 are recreation outgrants and Orange County Water District lands. With the exception of the Orange County Water District (OCWD) lands, these areas are administered by the COE and are recreation outgrants to San Bernardino County, Riverside County, and the City of Corona. The Counties and City are responsible for operation and management of the outgrants within COE guidelines. Areas not currently used for recreation may become agricultural outgrants on an interim basis. Specific site studies should take this information into account when siting either recreational or agricultural uses.

9-47 Orange County Water District lands occupy an estimated 2184.32 acres within the basin. OCWD lands are located on plate D-15 in addition to recreation outgrants because portions of OCWD lands are leased out for recreation purposes.

Agricultural Outgrants

9-48 Agricultural use of project lands is not an authorized purpose, rather an interim use to maximize land productivity and/or maintain open park-like areas consistent with the authorized purposes. Interim agricultural use is permitted where it is determined not to be detrimental to operational use, recreational use or wildlife habitat. Specific site studies should take this information into account when siting either recreational or agricultural uses.

9-49 As shown on plate D-16, agriculture outgrants are found primarily within master recreation leases to Riverside and San Bernardino Counties and the City of Corona. Agriculture outgrants are simply displayed as a single area, not classified by county or city. Refer to plate D-16 for designation of master recreation outgrant boundaries by ownership. Their present agricultural use is mainly open field crops. Agriculture outgrants may revert back to recreation outgrants at any time.

Major Flowage Easements

9-50 Areas delineated as major flowage easements, as noted in Plate D-17, are on private lands within the flood basin. They are primarily Orange County Water District land with other private land owners comprising the remainder of the area.

9-51 Flowage easements place two restrictions on the use of land. No major structures are permitted and no human habitation is allowed on these lands. Any structures proposed for construction on flowage easements must approved by the COE. Proposals will be evaluated based on the guidance provided in table D-3. Existing flowage easements occupy an estimated 3059.3 acres within the basin, plus the additional flowage easements that will be acquired between the 556' and 566' elevations.

Miscellaneous Utilities

9-52 The miscellaneous utilities displayed in plate D-18 include sanitation outgrants, major sewer lines, as well as the known locations of water wells. Sanitation outgrant classification includes: percolation ponds, effluent spreading areas, and water reclamation plants. Water well locations include wells controlled by three agencies: Orange County Water District, Santa Ana Watershed Project Authority and the Chino Basin Municipal Water District. These areas are indicated because they may contain potential constraints when encountered in specific site studies.

9-53 The sewer related items noted include Santa Ana Regional Interceptor. Regional interceptors represent sewer utilities placed to intercept water movement to prevent contamination of the ground water table. The interceptors provide for the removal of toxic materials and high salinity waste water as well as the transportation of non-reclaimable sewage.

X. MANAGEMENT AND COST SHARING

10-01 Initial recreation development within the Prado Basin began in 1976 under the Code 710 Program. The Code 710 Program - Recreation Development at Completed Corps of Engineer Projects was originally defined in Engineer Circular 11-2-119, dated 30 May 1975, and prescribed 50/50 cost sharing between the sponsoring local agency and the Federal Government. The initial amount spent on developed recreation facilities in Prado Basin by the Federal Government to date is approximately $3,600,000.00. The Code 710 Program has been an extremely successful program for the Los Angeles District and especially in the Prado Basin. Needed recreational facilities were developed quickly to meet a rapidly growing recreational demand within the market area surrounding Prado Basin. In light of the current Federal deficit and changing policy considerations within the COE, the Code 710 Program is currently not a funding priority in the COE.

10-02 Recreation is an authorized project purpose at the Prado Basin and based on this authorization recreation facilities may be considered for development with construction general funding as an integral part of the flood control project. Proposed recreation development would be cost shared with the appropriate local sponsor on a 50/50 basis, with all operation and management responsibilities being assumed by the local sponsoring agency. All proposed cost shared recreation facilities would have to be consistent with present COE policy guidelines, and engineering criteria.

10-03 During the initial reformulation of recreation studies for the Prado Basin there was no direct interest or ability on the part of any of the potential local sponsors to participate in the development of cost shared recreation facilities. Within the past year, however, as a result of a rather dramatic turnover in administrative personnel and introduction of a more aggressive viewpoint in meeting public recreation needs, this situation has changed. Supplement to the Phase II Design Memorandums will be prepared to address site specific recreation facilities based on this Resource Use Plan. Based on current policy

guidelines, the COE may enter into a cooperative planning effort with the County of San Bernardino, County of Riverside, and the City of Corona to develop an appropriate recreation plan and prepare the required cost sharing agreements. These three local sponsors have expressed interest in cost-sharing recreation facilities (see Chapter XII, Attachments).

XI. CONCLUSIONS AND RECOMMENDATIONS

11-01 This Resource Use Plan provides guidance for the future orderly development of the resources at the Prado Basin. The Plan establishes appropriate locations for high, low or no intense uses and provides criteria for development. As previously stated, it is not the purpose of this plan to be an absolutely definitive authority that details all specific development features which may be considered in the future. It is recognized that conflicts of land use may arise. In fact, there are potential conflicts with some of the existing land uses which have been "grandfathered" into the Plan. All specific proposals for future development will be evaluated on their merit subsequent to compliance with the National Environmental Policy Act of 1969. Conflicting land uses, whether currently proposed or to be proposed in the future, will not necessarily be precluded from development, as case by case mitigation measures are developed, approved and implemented to offset any impacts to significant resources.

11-02 The guidance provided in the Resource Use Plan ensures:

a. The utilization of the plan to serve as a guide for land use planning by the COE staff, county and local planning officials and private developers.

b. The Plan reflects Federal regulations and policy which minimizes flood damage to property and protects and enhances specific environmental resources.

c. The provision of guidelines for evaluating proposed uses and developments, including resource use objectives, resource element data, including existing land use, flood inundation level constraints and existing site feature data.

d. The preservation of the flood control integrity of the Prado Basin, and the appropriate consideration of proposed development.

11-03 It is recommended that the Prado Basin Resource Use Plan be approved as the basis of orderly development within the Prado Basin.

XII. ATTACHMENTS

12-01 Letter of intent to participate in the development of recreation facilities in the reservoir area of Prado Dam has been received from the Regional Parks Department of San Bernardino County, the Parks Department of Riverside County, and the Parks and Recreation Department of the City of Corona. These letters are inclosed herein as attachments.

REGIONAL PARKS DEPARTMENT

825 East Third Street • San Bernardino, CA 92415-0833 • (714) 387-2594

SAN BERNARDINO COUNTY
ENVIRONMENTAL
PUBLIC WORKS AGENCY

STEVEN K. MESSERLI
Director

February 12, 1988

Col. Tadahiko Ono
District Engineer
U. S. Army Corps of Engineers
P. O. Box 2711
Los Angeles, CA 90053 - 2325

Dear Colonel Ono:

Re: Santa Ana River Project - Water Resources Development Act of 1986

On February 2, 1988, I had the pleasure of meeting with the Corps of Engineers' Environmental Design Section staff to discuss the Santa Ana River Project that addresses cost sharing for recreation developments. On behalf of the San Bernardino County Regional Parks Department, this serves as our letter of intent to enter into a formal agreement and to confirm our active support and interest in cost sharing projects with the Corps of Engineers at Prado Regional Park.

Prado Regional Park is experiencing dramatic visitor growth. Visitor day use is expected to surpass 330,000 during 1988. During the last four years, the park has experienced a substantial increase in attendance, placing significant demand on the existing facilities at Prado Regional Park. With the projected population growth of the surrounding communities, our department must plan to meet the future recreation needs of the region. It is our intent and considered a high departmental priority to cost share recreation projects that will enhance and make available to the public areas at Prado Regional Park that are currently inaccessible.

The Regional Parks Department has developed a comprehensive planning study that identifies several projects that would meet the increasing demand for recreation facilities in the region as follows: development of additional family picnic and group campground facilities, access roads, parking lots, restrooms, picnic shelters, landscaping, irrigation and support facilities.

It is understood that this letter of intent does not obligate the Federal Government or San Bernardino County to proceed with future proposed development at Prado Regional Park.

We look forward to continuing our excellent working relationship with the Corps of Engineers in providing quality leisure services and facilities for public use at Prado Regional Park. If you have any questions or require additional information regarding this, please do not hesitate to contact me.

Sincerely,

Steven K. Messerli

STEVEN K. MESSERLI, Director
Regional Parks Department

SKM:PB:cm

cc: Larry Walker, Supervisor, Fourth District
B. L. Ingram, EPWA Administrator
Mike Walker, Deputy County Administrative Officer for Infrastructure
Richard Macias, Corps of Engineers

File: 8-10.1.1

COUNTY OF RIVERSIDE
PARKS DEPARTMENT
4600 Crestmore Road, P.O. Box 3507, Riverside, CA 92519 • (714) 787-2551

PAUL D. ROMERO
Director

February 23, 1988

Colonel Tadahiko Ono
Districting Engineer
U.S. Army Corps of Engineers
300 N. Los Angeles Street
Post Office Box 2711
Los Angeles, Ca 90053

Attention Raina Fulton

Dear Sir:

Prado Dam Basin

It is the desire of the Riverside County Parks Department to participate in the Recreation Cost Sharing Program for the Prado Dam Basin area. The actual scope of the project will be subsequently defined by the Army Corps of Engineers staff and Parks Department personnel.

The County will operate, maintain and make necessary replacements for the proposed facilities. Operation and maintenance costs can be submitted to you upon your request.

It is our understanding that your concurrence with this letter of intent does not obligate the Federal Government to approve or fund this project at this time.

Very truly yours,

Paul D. Romero

Paul D. Romero
Parks Director

PDR/JHH:mg
0459G

c: Sam Ford, Parks Department
George Balteria, Parks Department

To acquire, protect, develop, manage and interpret for the inspiration, use and enjoyment of all people, a well-balanced system of areas of outstanding scenic, recreation, and historic importance."

OFFICE OF: **PARKS AND RECREATION**

815 WEST SIXTH STREET (P.O. BOX 940), CORONA, CALIFORNIA 91718-0090

March 7, 1988

Colonel Tadahiko Ono, District Engineer
Los Angeles District, Corps of Engineers
P.O. Box 2711
Los Angeles, California 90053-2325

Subject: Letter of Intent for City of Corona to pursue the Recreational Development of Lease Area within Prado Basin on a Cost-Shared Basis with the Federal Government.

Dear Colonel Ono,

The purpose of this letter is to inform you of interest of this Department to pursue the recreational development of the City of Corona's lease area within the Prado Basin. In this development, it is our desire to participate with the Federal Government on a cost-share basis for the funding and construction of these recreational improvements.

The actual scope of these proposed improvements will be defined by this Department in cooperation with the Corps of Engineers.

It is my understanding that upon completion of these improvements, the City would operate and maintain these improvements and facilities.

It is our understanding that this "Letter of Intent" does not obligate the City of Corona at this time. Also, it is our understanding that this "Letter of Intent" does not obligate the Federal Government to approve or fund these recreational improvements at this time.

We are looking forward to working with the Corps of Engineers in providing these much needed recreational improvements in the Prado Basin.

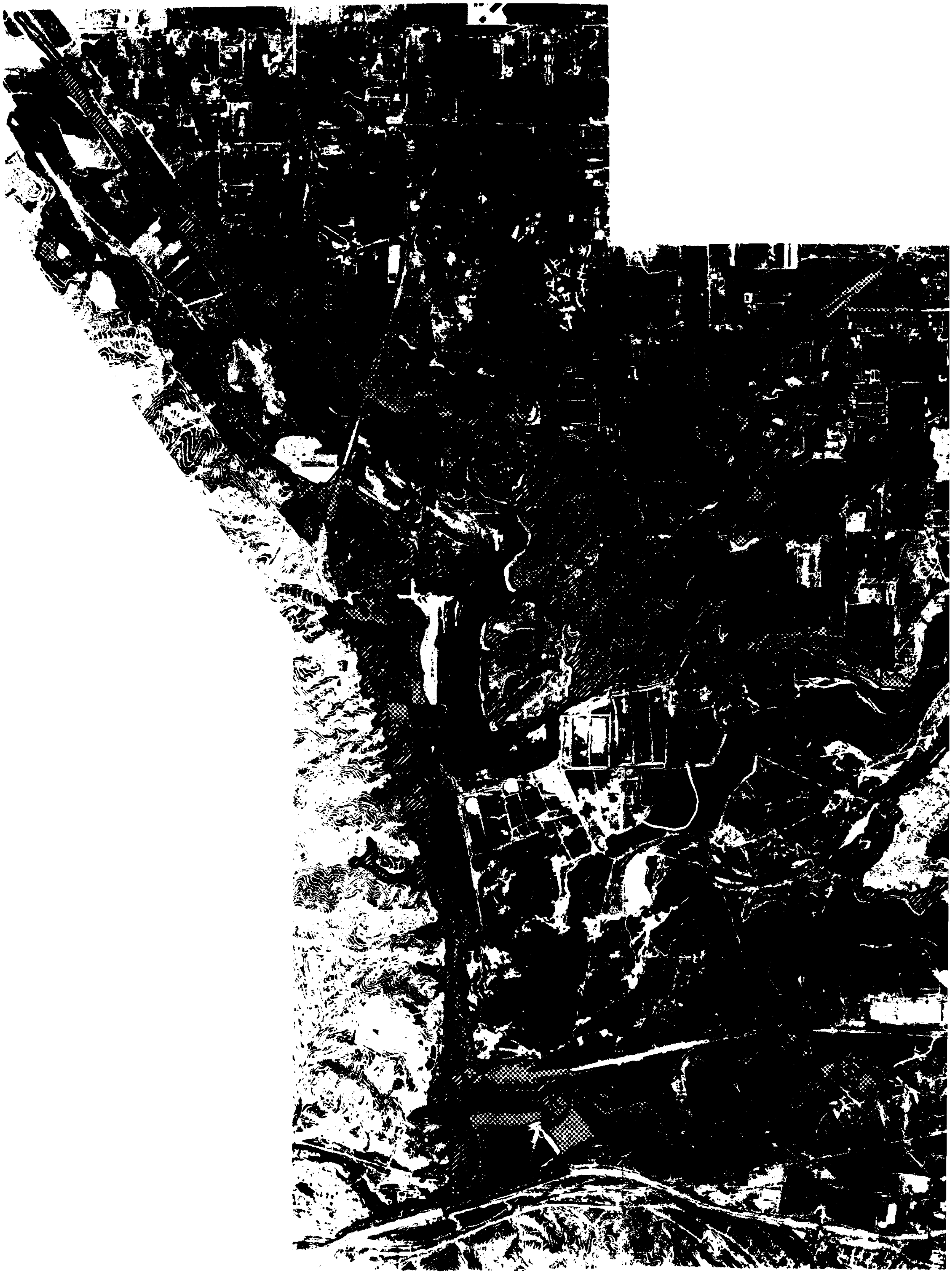
Jim E. Manning

Jim E. Manning, Director
Parks and Recreation Department

JEM/el

cc: Raina Fulton, Corps of Engineers

1



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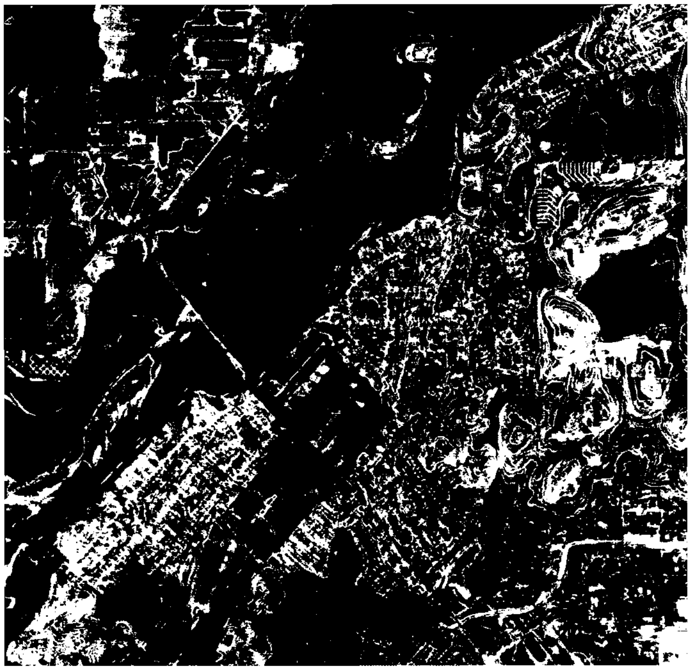
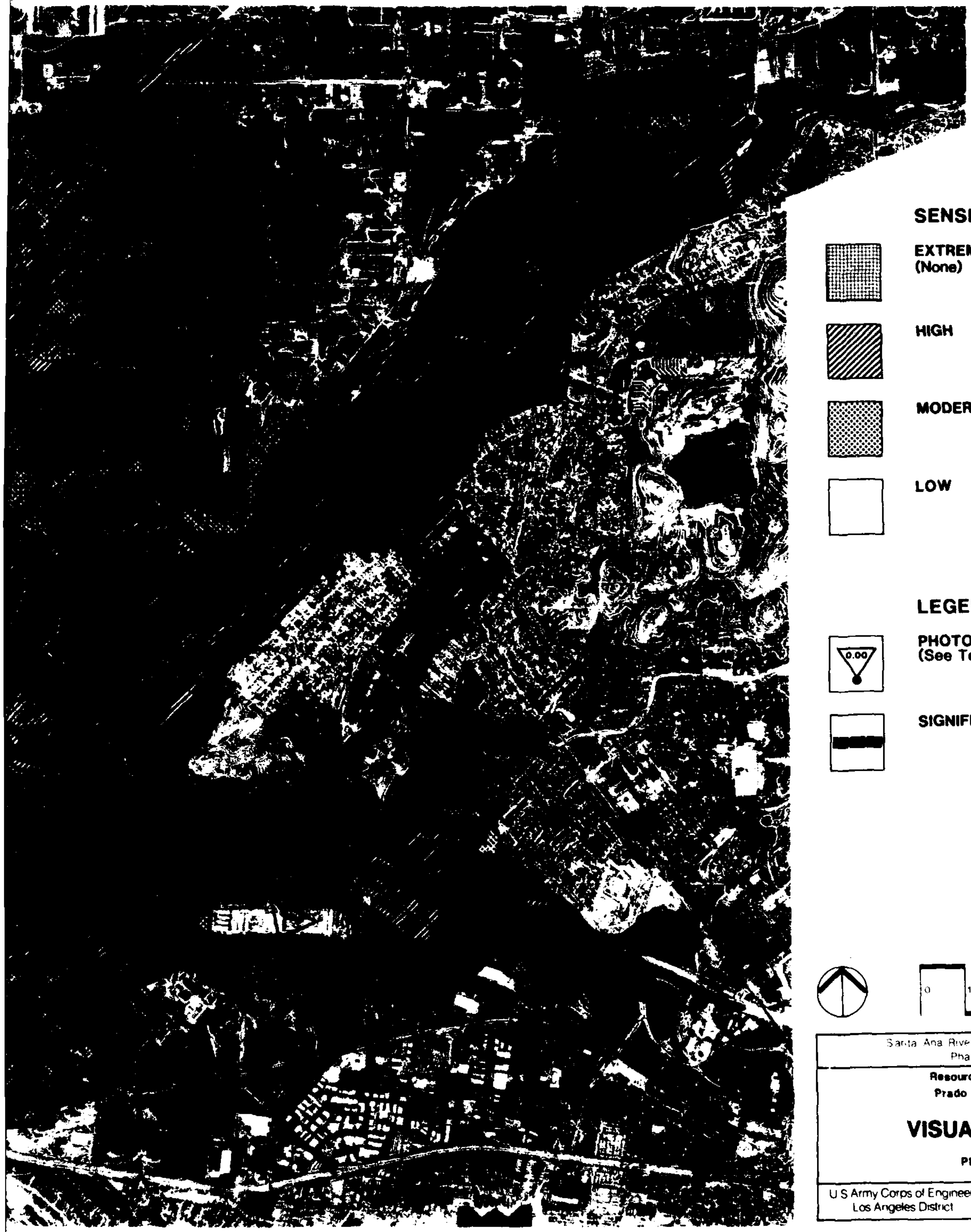




SENSITIVITY

▦ **EXTREME**
(None)

▨ **HIGH**

▒ **MODERATE**

☐ **LOW**

LEGEND

▽ **PHOTOS**
(See Text)

▬ **SIGNIFICANT ROADS**

0 1000 2000 3000 Feet 30 Acres

Santa Ana River Main Stem, California
Phase II GDM

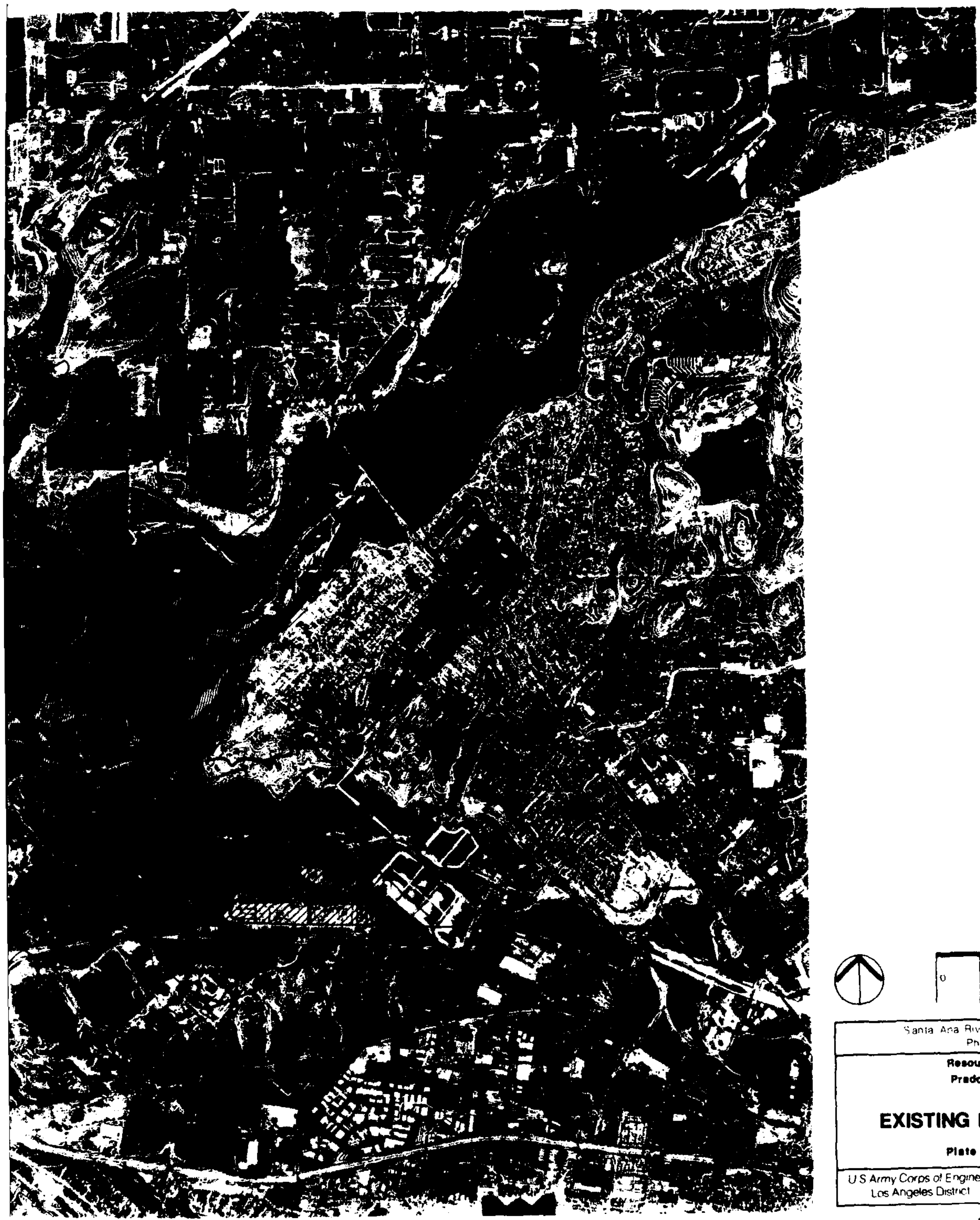
Resource Use Plan
Prado Dam Basin

VISUAL QUALITY

Plate D - 5

U S Army Corps of Engineers
Los Angeles District

2



Santa Ana River Main Stem, California
Phase II GDM

Resource Use Plan
Prado Dam Basin

EXISTING LAND USES

Plate D - 6

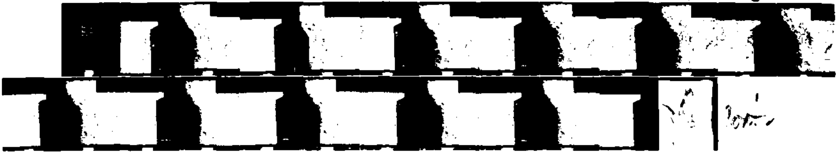
U S Army Corps of Engineers
Los Angeles District

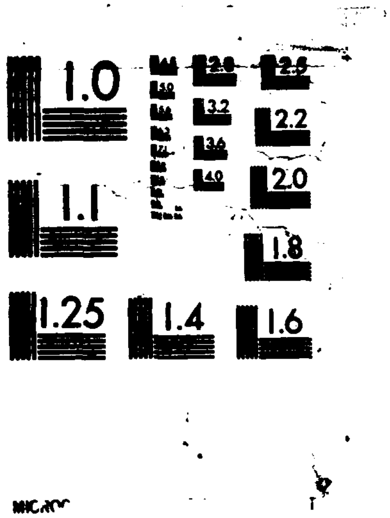
1

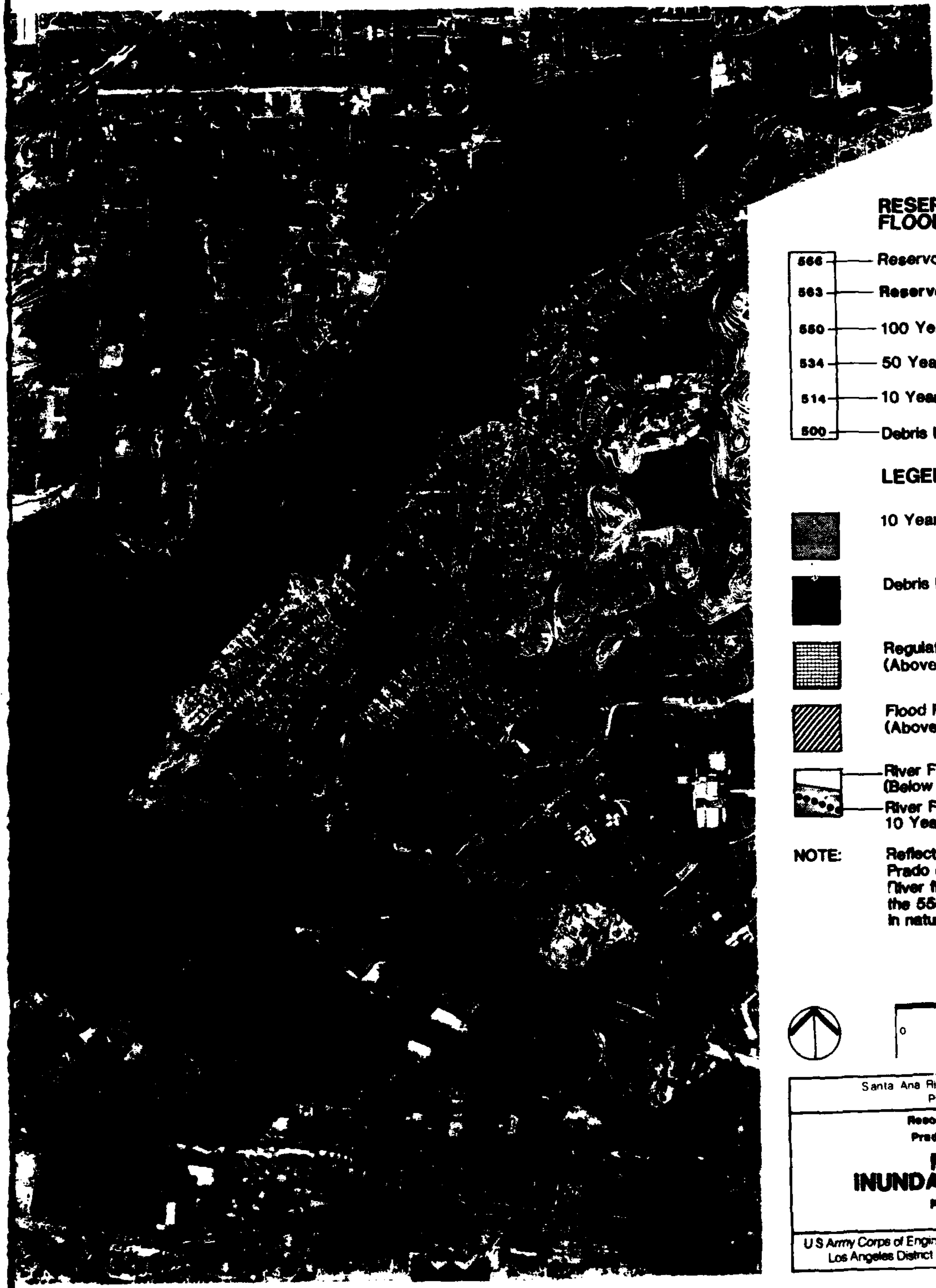
2

AD-A204 542 SANTA ANA RIVER DESIGN MEMORANDUM NUMBER 1 PHASE 2 GDM ON THE SANTA ANA R..(U) ARMY ENGINEER DISTRICT LOS ANGELES CA AUG 88 9/10

UNCLASSIFIED F/G 13/2 NL




1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6
MICROC



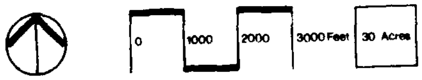
RESERVOIR AND FLOOD ELEVATIONS

566	Reservoir Take Line
563	**Reservoir Design Flood**
550	100 Year Flood
534	50 Year Flood
514	10 Year Flood
500	Debris Pool

LEGEND

▒	10 Year Floodplain Area
■	Debris Pool Area
▦	Regulatory Flood Way (Above 550 Elevation)
▨	Flood Fringe (Above 550 Elevation)
□	River Floodplain (Below 550 Elevation)
●	River Floodplain Edge Within 10 Year Flood

NOTE: Reflects upstream reservoir and Prado enlarged.
River floodplain boundaries (Below the 550 elevation) are preliminary in nature.



Santa Ana River Main Stem, California
Phase II GDM

Resource Use Plan
Prado Dam Basin

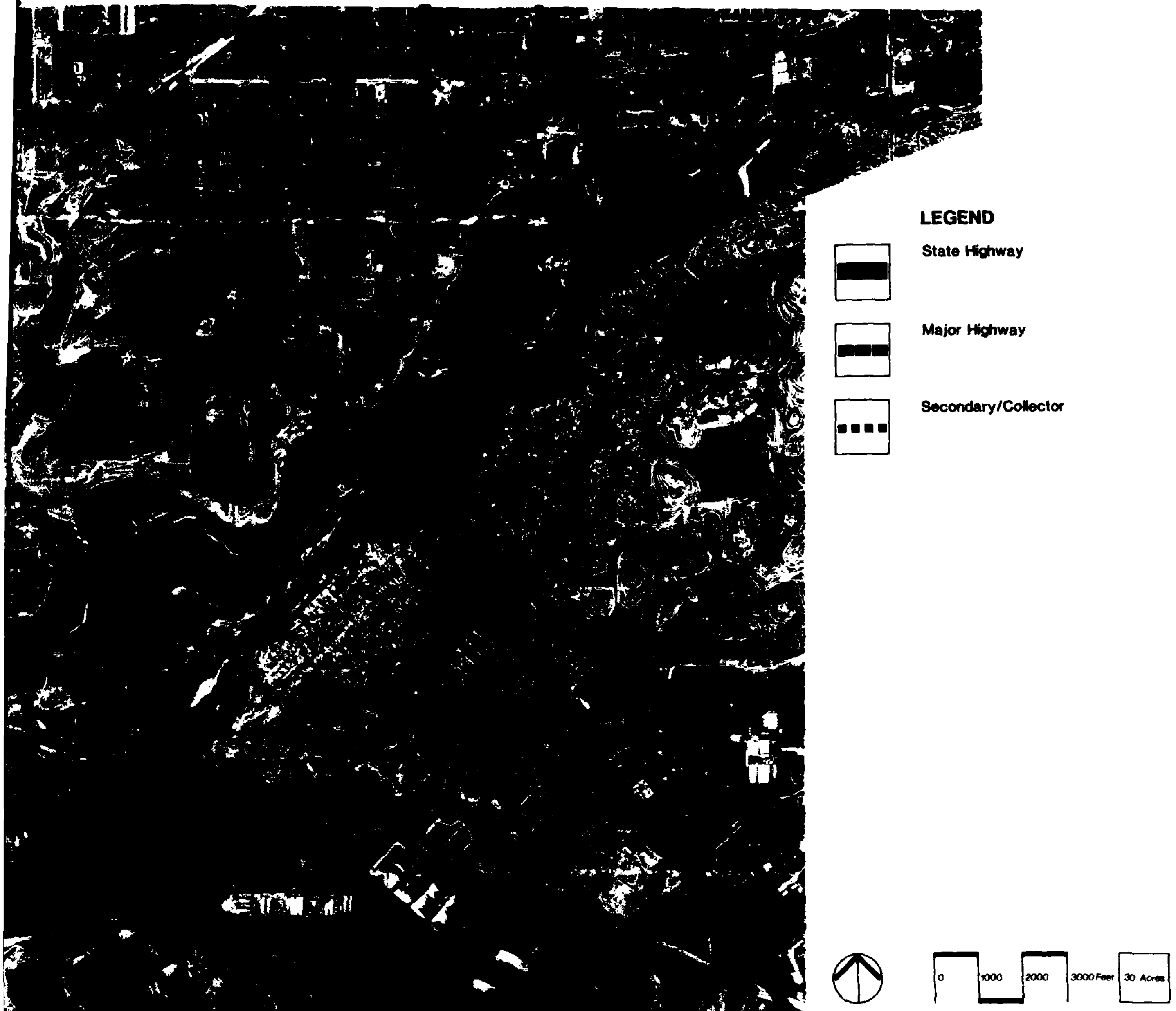
FLOOD INUNDATION LEVELS

Plate D - 7

U S Army Corps of Engineers
Los Angeles District

1

2



Santa Ana River Main Stem, California
Phase II GDM

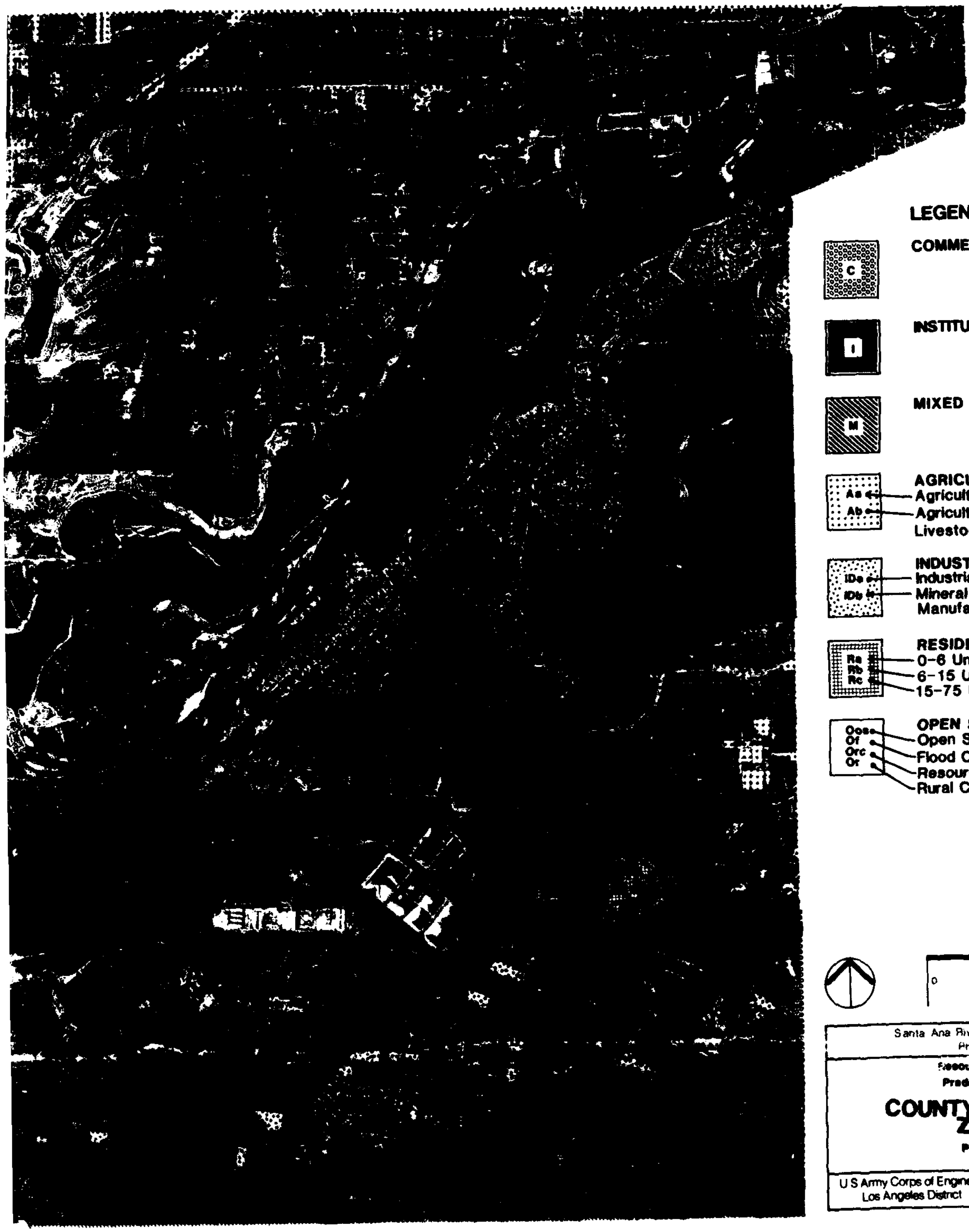
Resource Use Plan
Prado Dam Basin

CIRCULATION

Plate D - 6

U S Army Corps of Engineers
Los Angeles District

2



LEGEND

C	**COMMERCIAL**
I	**INSTITUTIONAL**
M	**MIXED USE**
	AGRICULTURAL
Aa	Agricultural
Ab	Agricultural & 0-2 Units/Acres & Livestock
	INDUSTRIAL
IDa	Industrial
IDb	Mineral Resources & Related Manufacturing
	RESIDENTIAL
Ra	0-6 Units/Acres
Rb	6-15 Units/Acres
Rc	15-75 Units/Acres
	OPEN SPACE
Oos	Open Space
Of	Flood Control Basin/Water Related
Orc	Resource Conservation
Or	Rural Conservation

0 1000 2000 3000 Feet

30 Acres

Santa Ana River Main Stem, California
Phase II GDM

Resource Use Plan
Prado Dam Basin

COUNTY AND LOCAL ZONING

Plate D - 9

U S Army Corps of Engineers
Los Angeles District

1

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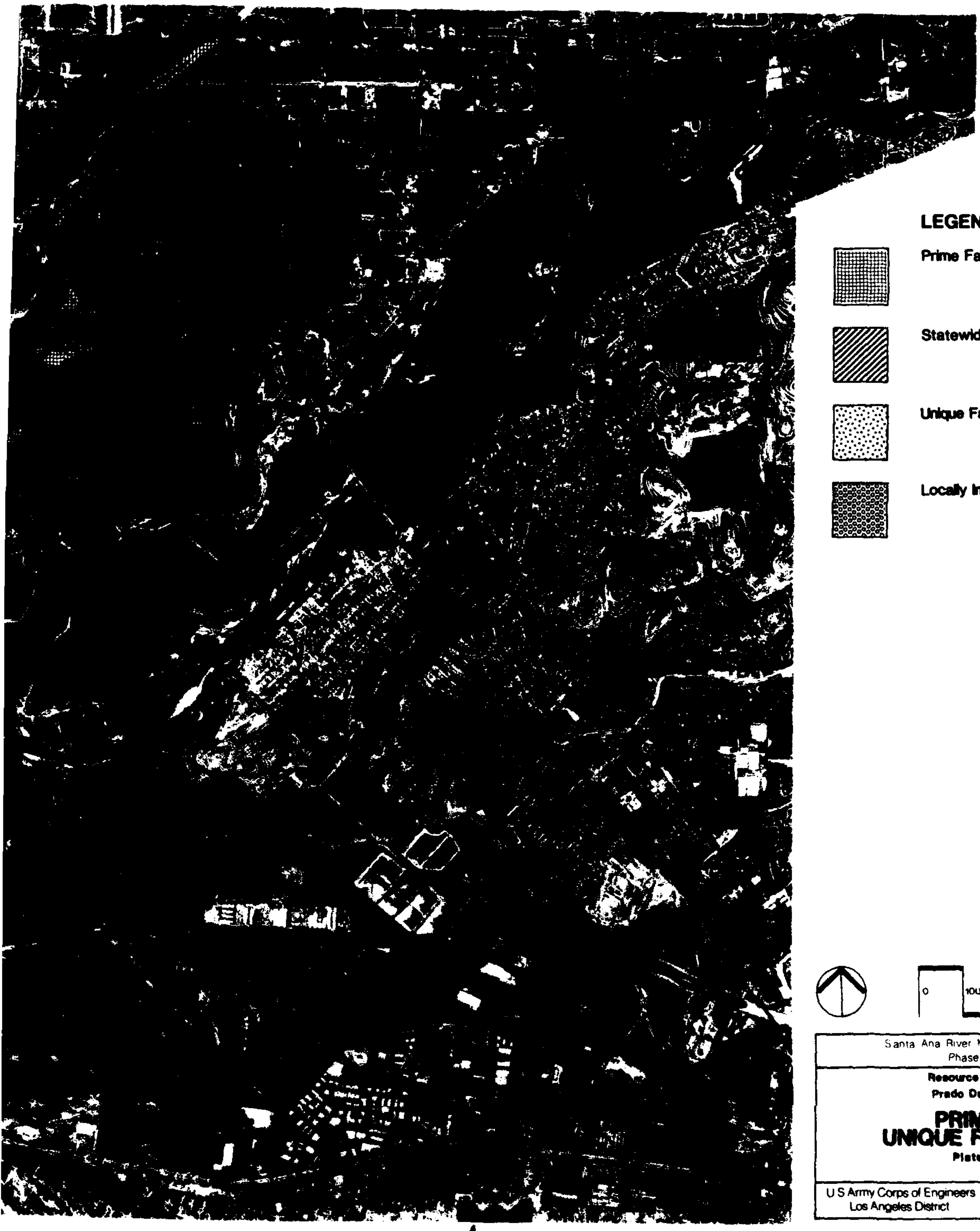


LEGEND

▦ Prime Farmlands

▨ Statewide Important Farmlands

░ Unique Farmlands

▩ Locally Important Farmland

0 1000 2000 3000 Feet

30 Acres

Santa Ana River Main Stem, California
Phase II GDM

Resource Use Plan
Prado Dam Basin

PRIME AND UNIQUE FARMLANDS

Plate D - 10

U S Army Corps of Engineers
Los Angeles District

1

2

LEGEND

▒ **Potential Borrow Area**

▦ **Landslide Debris**

▬ **Fault - Approximated**

●●●●● **Fault - Concealed**
(queried where conjectural)

0 1000 2000 3000 Feet | 30 Acres

Santa Ana River Main Stem, California
Phase II GDM

Resource Use Plan
Prado Dam Basin

GEOLOGY

Plate D - 11

U S Army Corps of Engineers
Los Angeles District

1

2

Index to Oil Leases

CA-12280 "ACTIVE"
Douglas B. Chaffee
Date of Grant: 5-1-82

PARCEL	ACRES
90	22 49
91	20 10
93-A	6.91
102	22 00
103	143.31
106-A	3 12
106-B	3 43
TOTAL	221 36

CA-11560 "ACTIVE"
William E. Jeffers
Date of Grant: 2-1-82

PARCEL	ACRES
56	13.92
503	
TOTAL	13.92

CA-11561 "ACTIVE"
Standard Energy Corp.
Date of Grant: 3-1-82

PARCEL	ACRES
8	8 92
13-B	51 75
115	5.00
123	10 00
124	15 75
125	73.04
126	9 71
127	11 99
128	2.00
129	29.94
132	1.58
133	2.50
134	1 14
TOTAL	223.32

CA-11563 "ACTIVE"
Alton Williams
Date of Grant:

PARCEL	ACRES
166	
333	162 63
334	
335	
TOTAL	162 63

CA-11565 "ACTIVE"
Roy C. Nesset
Date of Grant: 2-1-82

PARCEL	ACRES
34	37 12
TOTAL	37 12

il Leases

IVE"
ilse
5-1-82

:RES

	:2 49
	0 10
	6 91
	:2 00
	13 31
	3 12
	3 43
	21 36

TIVE"
ers
2-1-82

:RES

13 92

13 92

CA-11601 "ACTIVE"
Standard Energy Corp.
Date of Grant: 3-1-82

PARCEL	ACRES
6	8.92
13-B	51 75
115	5.00
123	10.00
124	15.75
125	73.04
126	9.71
127	11 99
128	2.00
129	29 94
132	1 58
133	2 50
134	1.14
TOTAL	223.32

CA-11563 "ACTIVE"
Alton Williams
Date of Grant:

PARCEL	ACRES
166	
333	162 63
334	
336	
TOTAL	162.63

CA-11566 "ACTIVE"
Roy C. Neset
Date of Grant: 2-1-82

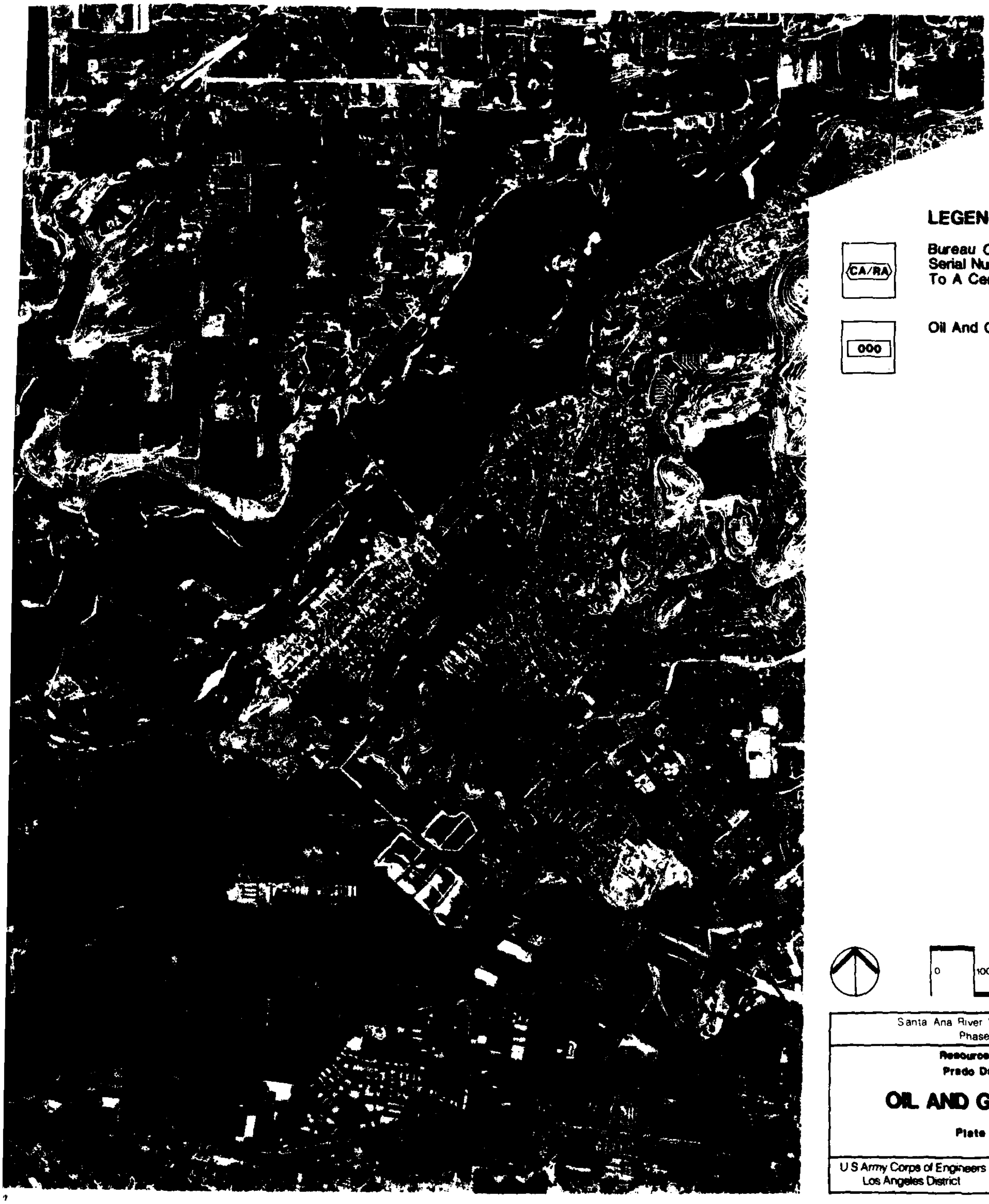
PARCEL	ACRES
34	37.12
TOTAL	37 12

R-02347 "PRODUCING"
The Hampton Oil Corp.
Date of Grant: 12-1-64

PARCEL	ACRES
201	19.86
206-A	24.83
206-B	54 02
212	40 28
213	43.00
213-A	31 63
250	9.92
282	15 97
283	5.89
284	11 28
286	14 28
289-A	19.13
326	65 95
328	182.48
TOTAL	538.52

R-07004 "PRODUCING"
Prado Petroleum
Date of Grant: 12-1-65

PARCEL	ACRES
154	
165	195.32
167	
TOTAL	195.32



LEGEND

CA/RA	**Bureau Of Land Management Serial Number Of Parcels Leased To A Certain Owner**
000	**Oil And Gas Number**

0 1000 2000 3000 Feet 30 Acres

Santa Ana River Main Stem, California
Phase II GDM

Resource Use Plan
Prado Dam Basin

OIL AND GAS LEASES

Plate D - 12

U S Army Corps of Engineers
Los Angeles District

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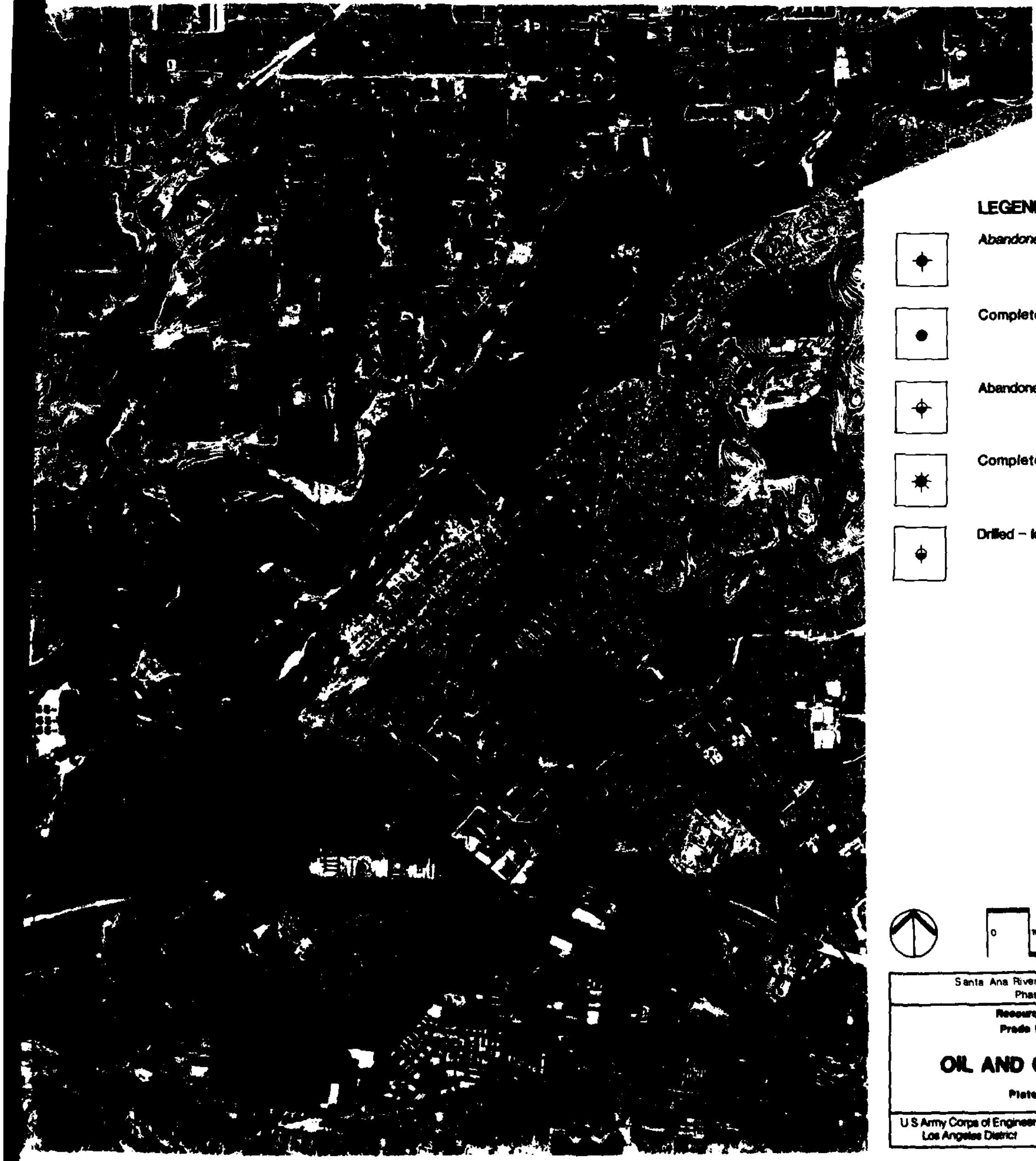

LEGEND

- ✦ *Abandoned Oil*
- ● Completed Oil
- ✧ Abandoned – Dry Hole
- ✷ Completed Gas
- ⊕ Drilled – Idle

0 1000 2000 3000 Feet | 30 Acres

Santa Ana River Main Stem, California
Phase II GDM

Resource Use Plan
Prado Dam Basin

OIL AND GAS WELLS

Plate D - 13

U S Army Corps of Engineers
Los Angeles District

1

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1

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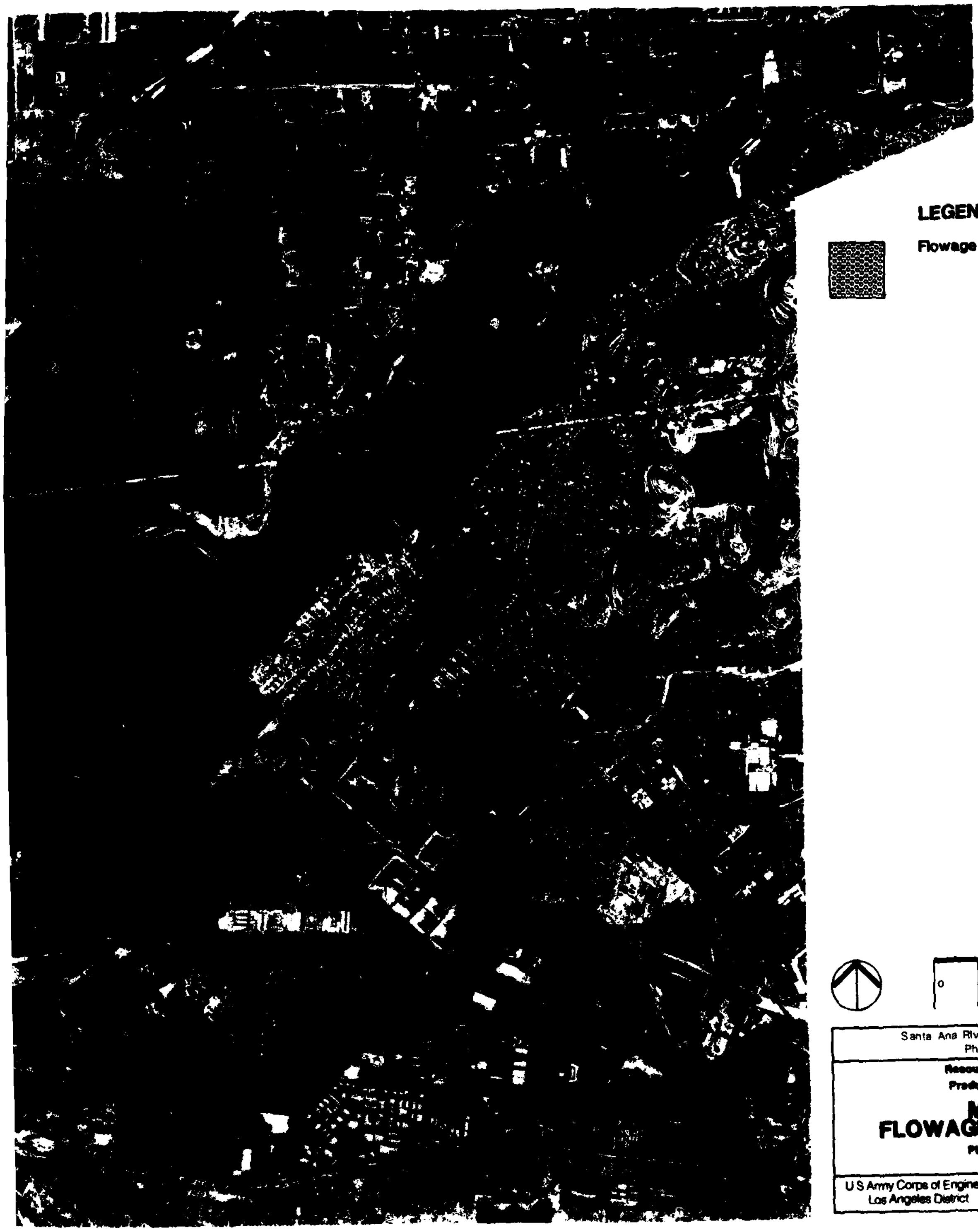
1



Santa Ana River Main Stem, California
Phase II GDM

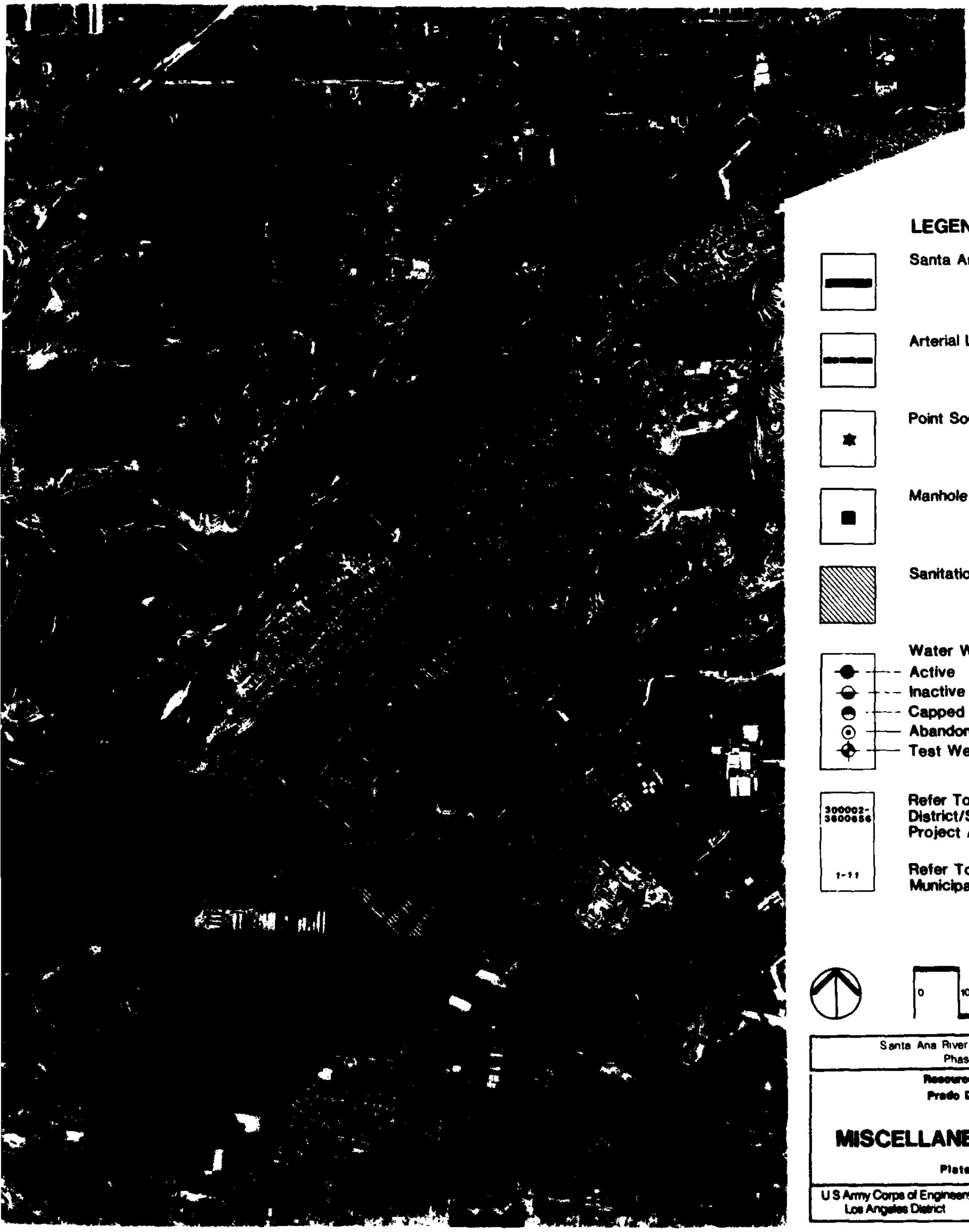
Resource Use Plan
Prado Dam Basin

MAJOR FLOWAGE EASEMENTS

Plate D - 17

U S Army Corps of Engineers
Los Angeles District

2



LEGEND

━	Santa Ana Regional Interceptor
╍	Arterial Lines
✱	Point Source Dischargers
■	Manhole
▨	Sanitation Outgrants

Water Wells
- ● Active
- ⊖ Inactive
- ◓ Capped
- ⊙ Abandoned
- ⊕ Test Wells

300002-3600656	Refer To Orange County Water District/Santa Ana Watershed Project Authority
1-11	Refer To Chino Basin Municipal Water District

0 1000 2000 3000 Feet 30 Acres

Santa Ana River Main Stem, California
Phase II GDM

Resource Use Plan
Prado Dam Basin

MISCELLANEOUS UTILITIES

Plate D - 18

U S Army Corps of Engineers
Los Angeles District

1

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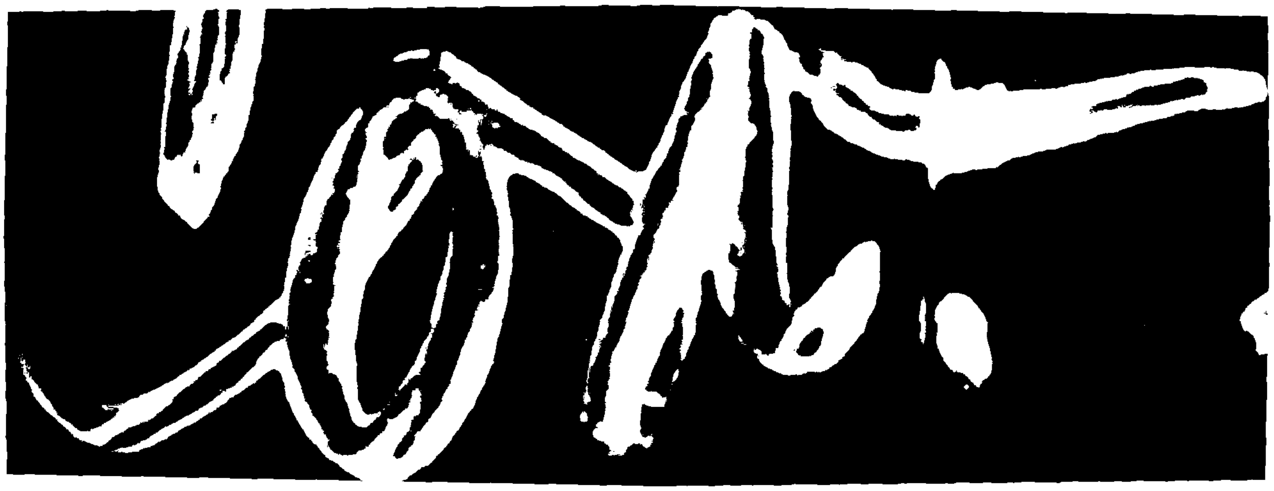
LMED

-8



Phase II GDM

Resource Use Plan
Prado Dam Basin

OIL AND GAS WELLS

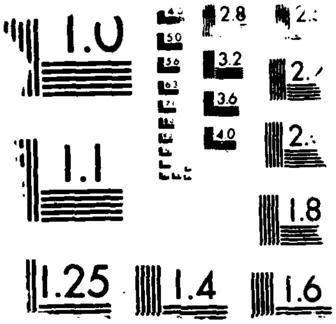
Plate D - 13

U S Army Corps of Engineers
Los Angeles District

1

2

AD-A024 542   TECHNICAL ASSISTANCE FOR TRANSPORTATION PLANNERS IN THE   0/10
US DEPARTMENT OF..(U) FEDERAL AVIATION ADMINISTRATION
WASHINGTON D C OFFICE OF AVIA..   G WILLIAMS ET AL.
UNCLASSIFIED   SEP 75 FAA-ASP-76-4   F/G 13/2   NL


1.0
1.1
1.25
1.4
1.6
1.8
2.8
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SUPPLEMENTARY

INFORMATION

Errata

AD-A204 542

DESIGN MEMORANDUM NO. 1

PHASE II GDM ON THE SANTA ANA RIVER MAINSTEM, INCLUDING SANTIAGO CREEK

DATED: AUGUST 1988

On November 15, 1988, the U.S. Army Corps of Engineers released, for agency and public review, the Congressionally authorized final General Design Memorandum (GDM) for the Santa Ana River Mainstem Project, including the Main Report and Supplemental Environmental Impact Statement, and accompanying volumes and technical appendixes. The Corps mailed copies of the final Phase II GDM to selected Federal, State, and local governmental agencies; elected officials within the project area; flood control districts; interest groups; and public libraries. Review of the final Phase II GDM by the agencies and the public generated comments which, in general, focused on the following concerns:

(a) Recreation trails along the Santa Ana River; (b) Aquatic habitat at Seven Oaks Dam; (c) Lower Santa Ana River sediment transport and potential beach degradation; (d) Esthetics and construction phasing for the Santiago Creek channel improvements; and (e) Flood threat and associated impacts to the Corona Airport within the Prado Dam. Inclosure 1 presents a synopsis of the U.S. Army Corps Engineers response to these concerns.

Following publication of the final Phase II GDM, several inconsistences were noted that require clarification of certain statements, and correction of typographical errors. The errata sheets (Inclosure 2) provide the revisions to be incorporated in the final Phase II GDM.

For additional information you may direct your inquiries to the following:

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Encls

for
Tadahiko Ono
Colonel, Corps of Engineers
District Engineer

U.S. ARMY CORPS OF ENGINEERS
RESPONSES TO AGENCY AND PUBLIC REVIEW COMMENTS
ON
DESIGN MEMORANDUM NO. 1
PHASE II GENERAL DESIGN MEMORANDUM
ON THE SANTA ANA RIVER MAINSTEM, INCLUDING
SANTIAGO CREEK
DATED: AUGUST 1988

RECREATION TRAILS ALONG THE SANTA ANA RIVER

ISSUE - The Main Report and Supplemental Environmental Impact Statement indicated that the equestrian trails in several locations along the Santa Ana River would be a continuous paved surface. Comment was made that this would constitute an unacceptable conversion of use since the existing trails are unpaved.

RESPONSE - The Corps and Orange County, one of the sponsors, will be developing several alternative solutions in coordination with the National Park Service to resolve this issue. One solution would be to locate the trail along the toe of the levee, while a more promising one may be to use excess spoil material to widen the top of the levee within the existing rights-of-way. We anticipate that this issue can be successfully resolved.

AQUATIC HABITAT AT SEVEN OAKS DAM

ISSUE - Concern was for the need for additional mitigation measures to compensate for impacts on aquatic habitats at the Seven Oaks damsite.

RESPONSE - The recommended mitigation plan to compensate for impacts resulting from the Seven Oaks Dam portion of the project was evaluated, and project related impacts and achievable mitigation goals were defined. The evaluation indicated that the mitigation plan for Seven Oaks Dam will meet 14.5% of the mitigation goal for aquatic habitat. Following coordination with the various resource agencies, no mitigation options were found which would achieve 100% mitigation under current Corps policy on mitigation. The Corps agrees that the aquatic habitat is impacted and has identified the magnitude of the impact according to NEPA requirements. The Corps has considered all practicable mitigation options in fulfilling its 404(b)(1) requirements. The project has been determined to not be contrary to the public interest even though 100% mitigation of impacts is not achieved.

LOWER SANTA ANA RIVER - SEDIMENT TRANSPORT & BEACH DEGRADATION

ISSUE - Concern was for impacts of the project on coastal beaches and that the project does not assure commitments to mitigate for these adverse impacts.

RESPONSE - The concern was based on the statement in the SEIS, page V-57, paragraph 5-192, which stated that there would be a reduction in sediment available for beach replenishment as a result of the project. Upon close scrutiny of the aforementioned paragraph we find that the statements contained therein are erroneous and was inadvertently included in the SEIS. Volume 3, Lower Santa Ana River, presents results of the sediment transport analysis which indicates that there would be a net increase of 11,000 cubic yards of sediment per year available for beach replenishment with the project in place. Accordingly, the aforementioned paragraph in the SEIS will be revised to read as follows:

"Under existing channel conditions, large floods will breach levees causing flood flows and sediment to exit and deposit onto the Santa Ana River Flood Plain. With the project channel improvements, large flood flows (up to 190 year frequency) will remain in the channel, thus causing any sediment that would have been deposited in the floodplain to be deposited in the channel itself or conveyed to the ocean. With the Santa Ana River project in place, sand-sized sediment yield (average annual basis) is estimated to increase by 11,000 cubic yards."

The Corps has held several meetings with staff members of both the California Coastal Commission and the City of Newport Beach to resolve the issue of placement of compatible channel material on the beach. The discussions appear to be headed to a mutually acceptable agreement.

ESTHETICS AND CONSTRUCTION PHASING FOR THE SANTIAGO CREEK CHANNEL IMPROVEMENTS

ISSUE - The concern was raised regarding the channel design and construction phasing of Santiago Creek, and the associated esthetics impacts of the project.

RESPONSE - The design displayed in the report for the stabilization of Santiago Creek between the Santa Ana Freeway and the Santa Ana River reflects the minimum amount of construction required to reliably and economically protect the streambed and banks of the creek from erosion. This design was developed after carefully consideration of the desires of residents along the creek as expressed in numerous public involvement meetings, and as the result of detailed investigation of several alternatives. The Corps of Engineers cannot support any lesser level of improvement as being sufficiently reliable. If this reach of channel is not stabilized to the minimum level shown in the report, significant erosion of the stream banks with potentially disastrous damage to property immediately adjacent to the creek on both sides would occur during controlled design flood releases from the detention basin. If the reach of the Santiago Creek from the Santa Ana Freeway to the Santa Ana River is not sufficiently stabilized, the flood control project cannot be safely operated as designed. In regards to the construction phasing for Santiago Creek it is not advisable to construct the upstream flood control improvement <u>prior</u> to commencing

any construction downstream of the freeway because of the need to have the lower channel in place to operate the detention pits.

FLOOD THREAT TO THE CORONA AIRPORT WITHIN PRADO BASIN

ISSUE - Concerns were raised about the potential flood threat at the Corona Airport as a result of the Corps recommended modifications to Prado Dam.

RESPONSE - The Corps studies indicate that the recommended Prado modifications will enable us to make larger releases from Prado Dam, thus allowing faster drawdown of the flood control pool. Consequently, within the period of the current airport lease, the frequency and duration of flooding at the airport will be reduced with the recommended modification of Prado Dam. Should interests at the airport feel that a levee is imperative to protect the airport from frequent flooding while allowing impoundment during major storm events, they would need to identify a local financial sponsor to bear the full costs for the levees and for the costs for mitigative measures resulting from the construction of the levees. These costs are entirely non-Federal expenses. It is noted that the Corona Airport is located on lands owned by the Federal Government for the purpose of flood control and all investments in this location were made with the full knowledge of the flood threat. As our recommended modifications will not result in more frequent or longer durations of flooding, the Corps did not include flood protection features at this location.

AD-A204542

VOLUME 2

PRADO DAM

ERRATA

1. GEOTECHNICAL APPENDIX B

Page B-II-5, Paragraph 2-11, end of paragraph. Insert "Additional investigations to identify the bedrock surface will be conducted during plans and specifications."

Page B-IX-13, Paragraph 9-29, end of paragraph. Insert "Additional investigations to identify the bedrock surface will be conducted during plans and specifications."

Page B-XV-3, Paragraph 15-11, end of paragraph. Insert "Additional investigations to identify the bedrock surface will be conducted during plans and specifications."

END
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